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ENVIRONMENTAL RESTORATION  
DIVISION DMC



K/HS-132

**ORGDP**

**OAK RIDGE  
GASEOUS  
DIFFUSION  
PLANT**

**MARTIN MARIETTA**

**RCRA FACILITY INVESTIGATION PLAN  
GENERAL DOCUMENT  
OAK RIDGE GASEOUS DIFFUSION PLANT  
OAK RIDGE, TENNESSEE**

**MARCH 1987**

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TIN MARIETTA ENERGY SYSTEMS, INC.  
THE UNITED STATES  
RTMENT OF ENERGY

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Title/Subject RCRA FACILITY INVESTIGATION PLAN  
GENERAL DOCUMENT, ORGDP, OAK RIDGE, TENNESSEE

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Kevin S. Lewis  
K-25 Classification & Information Control Officer

3/25/93  
Date

MARCH 1987

K/HS-132

RCRA FACILITY INVESTIGATION PLAN  
GENERAL DOCUMENT  
OAK RIDGE GASEOUS DIFFUSION PLANT  
OAK RIDGE, TENNESSEE

Prepared by the  
Oak Ridge Gaseous Diffusion Plant  
Oak Ridge, Tennessee 37831  
operated by  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
for the  
U. S. DEPARTMENT OF ENERGY  
under contract DE-AC05-84OR21400

## TABLE OF CONTENTS

1.0	INTRODUCTION . . . . .	1
2.0	OBJECTIVES OF RCRA FACILITY INVESTIGATION PLANNING . .	3
2.1	OBJECTIVES . . . . .	3
2.2	CRITERIA . . . . .	3
2.3	PROPOSED SWMUS REQUIRING RCRA FACILITY INVESTIGATION PLANS . . . . .	5
2.4	FEASIBLE ALTERNATIVES . . . . .	5
2.5	RISK ASSESSMENT . . . . .	5
3.0	DESCRIPTION OF CURRENT CONDITIONS . . . . .	9
3.1	GEOGRAPHICAL INFORMATION . . . . .	9
3.2	HISTORICAL INFORMATION . . . . .	16
3.3	OPERATIONAL INFORMATION . . . . .	22
4.0	CHARACTERIZATION OF THE ENVIRONMENTAL SETTING . . . . .	28
4.1	GENERAL . . . . .	28
4.2	SUBSURFACE GEOLOGY . . . . .	28
4.3	SURFACE WATER . . . . .	40
4.4	AIR . . . . .	48
5.0	IDENTIFICATION OF POTENTIAL PATHWAYS OF MIGRATION AND POTENTIAL RECEPTORS . . . . .	53
5.1	POTENTIAL PATHWAYS OF MIGRATION . . . . .	53
5.2	POTENTIAL RECEPTORS . . . . .	55
5.3	TERRESTRIAL FLORA AND FAUNA . . . . .	57
5.4	GENERAL OBSERVATIONS . . . . .	63
6.0	STATISTICAL SAMPLING PLAN . . . . .	65
6.1	SAMPLING PLAN STRATEGIES . . . . .	65
6.2	SAMPLE QUALITY . . . . .	65
6.3	GENERAL STRATEGIES . . . . .	66
6.4	FEATURES OF SAMPLING . . . . .	68
6.5	NUMBER OF SAMPLES . . . . .	70
6.6	SITE-SPECIFIC DETAILS . . . . .	71
7.0	SAMPLING AND ANALYTICAL METHODOLOGY . . . . .	72
7.1	SAMPLING METHODOLOGY . . . . .	72
7.2	ANALYTICAL METHODOLOGY . . . . .	77
7.3	QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES . .	90
7.4	SAMPLE HANDLING AND PROCESSING . . . . .	91
7.5	IMPLEMENTATION . . . . .	92
8.0	DATA MANAGEMENT PROCEDURES . . . . .	95
9.0	HEALTH AND SAFETY PROCEDURES . . . . .	97
9.1	HEALTH AND SAFETY ORGANIZATIONS AT ORGDP . . . . .	97
9.2	PLANT SUPPORT AND PROTECTION (PS&P) DIVISION . . .	97
9.3	HEALTH, SAFETY AND ENVIRONMENTAL AFFAIRS DIVISION.	101

TABLE OF CONTENTS (cont.)

9.4	HEALTH AND SAFETY RESPONSIBILITY DURING RCRA FACILITY INVESTIGATIONS . . . . .	105
9.5	ORGDP QUALITY ASSURANCE . . . . .	123
9.6	GENERAL HEALTH AND SAFETY PROCEDURES FOR RFI . . .	125
APPENDIX A	. . . . .	128

## 1. INTRODUCTION

The 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) address corrective actions for continuing releases from hazardous waste treatment storage, or disposal facilities. Under this provision, any facility applying for a RCRA Part B permit will be subject to an assessment of all solid waste management units (SWMUs) at the facility. If any SWMU is suspected to be the source of contaminant release to the environment, a RCRA Facility Investigation (RFI) may be required to define the nature and extent of the release. The major facilities, located within the confines of the Oak Ridge Reservation (ORR) and operating hazardous waste treatment, storage, or disposal facilities, are the Oak Ridge Gaseous Diffusion Plant (ORGDP), the Oak Ridge National Laboratory (ORNL), and the Y-12 Plant. The first RCRA permit to be approved for the ORR under the new HSWA requirements was a hazardous waste storage building at ORNL. Under the conditions of Section 2.A.1 of the permit (effective in October 1986), general information must be provided on all SWMUs located within the ORR by April 1987. Specific SWMUs requiring further study will be identified from this information, and a RCRA Facility Investigation (RFI) Plan will be prepared for each of them.

This document provides general information in support of RFI plans for SWMUs located within the jurisdiction of the ORGDP. This document will serve as a reference volume for the RFI plans which will be submitted on the individual ORGDP site SWMUs. General RFI Plan objectives, SWMUs and locations, and a schedule

for site specific RFI plans are identified. The report places the SWMUs in the ORGDP geographical setting and in a perspective of both the prior and current scope of operations. The characteristics of the ORGDP environmental setting are discussed in some detail and potential receptors are identified. Sampling strategies, quality assurance and control associated with sampling and analysis, and data management procedures are covered. Finally, the organizations and functions which support the ORGDP Health and Safety programs are reviewed together with the policies, standards, and procedures which were established to protect the health and safety of employees and the public.

The development of the RFI plans is based on "RCRA Facility Investigation Guidance," October 1986, from the U. S. Environmental Protection Agency (EPA) Waste Management Division, Office of Solid Waste.

Documentation is being prepared separately for SWMUs under the jurisdiction of other ORR plants.

## 2. OBJECTIVES OF RCRA FACILITY INVESTIGATION PLANNING

### 2.1 OBJECTIVES

The RFI Plan will identify actions necessary to characterize the nature and extent of any releases of hazardous constituents from SWMUs into soils, groundwater, vegetation, surface water, or air. The plans will be used as a basis for RCRA Facility Investigations.

### 2.2 CRITERIA

In designing statistically valid sampling plans, objectives must be clearly defined. Data needs must be identified so that sampling may be focused on the specific subareas, matrices, or contaminants of interest. The primary objective is to characterize the nature and extent of any release of hazardous constituents. General criteria are established below, and specific criteria will be established for each SWMU RCRA investigation as needed.

The primary media of interest are groundwater, surface water, and soils. A list of constituents of interest based on 40 CFR 261, Appendix 9, and best technical judgement will be developed for each SWMU of interest. Four quarters of RCRA groundwater monitoring data covering the parameters listed in Table 2.1 will be collected for all applicable sites under the ORGDP Groundwater Protection Program. The sampling methodology and analytical procedures will be designed to characterize the contaminants of interest at or below the levels summarized in

Table 2.1. ORGDP RCRA groundwater monitoring parameters

Alpha Activity	Niobium
Aluminum	Nitrate (as Nitrogen)
Antimony	pH
Arsenic	Phenols
Barium	Phosphorus
Beryllium	Potassium
Beta Activity	Selenium
Boron	Silicon
Cadmium	Silver
Calcium	Silvex
Chloride	Sodium
Chromium	Strontium
Cobalt	Sulfate
Conductivity	Temperature
Copper	Thallium
Endrin	Thorium
Extractable Organics	Titanium
Fluoride	Total Coliform Bacteria
Groundwater Elevation	Total Organic Carbon
Iron	Total Organic Halogen
Lead	Total Radium
Lindane	Toxaphene
Lithium	Uranium-235
Magnesium	Uranium-238
Manganese	Vanadium
Mercury	Volatile Organics
Methoxychlor	Zinc
Molybdenum	Zirconium
Nickel	2,4-D



Table 2.2. For contaminants not listed in Table 2.2, characterization levels will be based on existing regulatory limits or best technical judgement. If contaminant concentrations exceed the established levels, more work may be needed to characterize the extent of the release.

### 2.3 PROPOSED SWMUS REQUIRING RCRA FACILITY INVESTIGATION PLANS

RFI plans are scheduled to be written on the SWMUs listed in Table 2.3.

### 2.4 FEASIBLE ALTERNATIVES

Potential corrective measures for each SWMU will be identified in the site specific document. The RFI plans are designed to obtain the bulk of the information necessary to support feasibility studies. The remedial action alternatives that will be evaluated will include those addressed in EPA Handbook, Remedial Action at Waste Disposal Sites (Revised), EPA/625/6-85/006.

### 2.5 RISK ASSESSMENT

The public health risk resulting from the remedial action alternatives for each SWMU will be evaluated. This evaluation will consist of a characterization of contaminant sources, environmental setting, magnitude of release, pathways to human exposures, and characterization of risks. Risk assessment will begin early in the RI/FS process since it will be useful for

Table 2.2. Hazardous substance guidelines

<u>Analyte</u>	<u>Max. limit, water (mg/l)</u>	<u>Max. limit, soil (mg/kg)</u>	<u>Reference</u>
Benzene	0.025	2.5	6
Ethylbenzene	1.4	140	1
Toluene	14.3	1430	1
Carbon tetrachloride	0.025	2.5	6
Chloroform	0.002	0.2	1
1,2-Dichloroethane	0.26	26	6
1,1-Dichloroethylene	0.35	35	6
Methylene chloride	0.15	15	2
Tetrachloroethylene	0.085	8.5	6
Trichloroethylene	0.26	26.0	6
1,1,1-Trichloroethane	1.0	100	6
Acetone	20	2000	7
Ethylacetate	400	40,000	4
Xylenes	0.62	62	2
Methyl ethyl ketone	0.75	75	5
Methyl isobutyl ketone	100	10,000	4
Vinyl chloride	0.06	6.0	6
Naphthalene	0.025	2.0	1
Pentachlorophenol	1.01	101	1
Cyanide	0.2	10	3,8
Phenol	0.3	30	1,8
Copper	1	100	3
Zinc	5	500	3,8
Nickel	0.2	400	3,8
Mercury	0.002	4	3,8
Arsenic	0.05	100	3,8
Cadmium	0.01	20	3,8
Chromium	0.05	100	3,8
Silver	0.05	100	3,8
Lead	0.05	100	3,8
PAH's	0.1	100	3,8
PCB's	0.001	100	
Nitrates (N)	10	N.A.	
Sulfates	250	N.A.	
Phosphate	50	N.A.	

## References:

1. Federal Register, 45:231, Nov. 1980
2. Long term SNARL
3. Interim Drinking Water Standard
4. Dangerous Properties of Industrial Materials. N. Irving Sax
5. 10-day SNARL
6. Federal Register, 49:114,24338, June 1984
7. Flash point concentration.
8. Based on E. P. Toxicity limit or suggested level  
(Phenol, cyanide, nickel)

Table 2.3. Proposed list of SWMUs and schedule

<u>Proposed SWMUs</u>	<u>RFI Plan Submittal Date</u>
1. K-1070-A Old Contaminated Burial Ground	C Y - 8 7
2. K-1070-B Old Classified Burial Ground, K-1407-A Neutralization Pit, K-1407-B Pond, and K-1700 Watershed <sup>1</sup>	CY-87
3. K-1070-C/D Classified Burial Ground	CY-87
4. K-901A Holding Pond	CY-87
5. K-1064 Burn Area Peninsula Storage	CY-87
6. K-770 Scrap Metal Yard & Contaminated Debris	CY-88
7. K-1420 Oil Storage	CY-88
8. K-1410 Neutralization Pit	CY-88
9. K-1420 Mercury Recovery Room	CY-88
10. K-1401 Acid Line	CY-88
11. K-1232 Treatment Facility	CY-88
12. K-1413 Neutralization Pit	CY-88
13. K-1420 Process Lines	CY-88
14. K-1004 Area Lab Drain	CY-88
15. K-1070-F Old Contractors Burial Ground	CY-88

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<sup>1</sup>Although the K-1700 Watershed is not a SWMU, the extent of contamination in the K-1700 Watershed will be assessed due to its proximity to SWMUs.

determining data requirements and may influence site sampling plans. The range of complexity, level of detail, and degree of quantification necessary at individual SWMUs will depend on results of site characterization studies. Risk assessment input will be used to identify remedial alternatives which eliminate significant risks posed by the site. Numerical design goals for remedial alternatives will be based on chemical concentration standards if available (See Table 2.2). Otherwise, a target carcinogenic risk range will be used to develop goals.

### 3. DESCRIPTION OF CURRENT CONDITIONS

#### 3.1 GEOGRAPHICAL INFORMATION

##### 3.1.1 Vicinity Map

The Oak Ridge Gaseous Diffusion Plant (ORGDP) site lies in the valley between the Cumberland and the Southern Appalachian Mountains in East Tennessee. The plant is actually located in the western end of the city of Oak Ridge, Tennessee, which is midway between the Kentucky and Georgia borders. The vicinity map in Figure 3.1 shows Oak Ridge's location to be the center of a north-south line from Lexington, Kentucky, and Atlanta, Georgia, and an east-west line from Asheville, North Carolina, to Nashville, Tennessee. Interstates 75 and 40 serve the area.

##### 3.1.2 Location Map

A location map in Figure 3.2 shows the DOE reservation of approximately 36,000 acres and how the ORGDP geographically relates to the city of Oak Ridge and the other two major government facilities in the area -the Oak Ridge National Laboratory (ORNL) and the Oak Ridge Y-12 plant. A good road network ties the ORGDP to the City of Oak Ridge and Knoxville, to Interstates 40 and 75 and to the other two facilities, ORNL and Y-12.

##### 3.1.3 Aerial View

Figure 3.3 is an aerial view of ORGDP, which is situated on 1700 acres of land with 700 acres enclosed in security fencing. There are 220 principal buildings having a roof area of

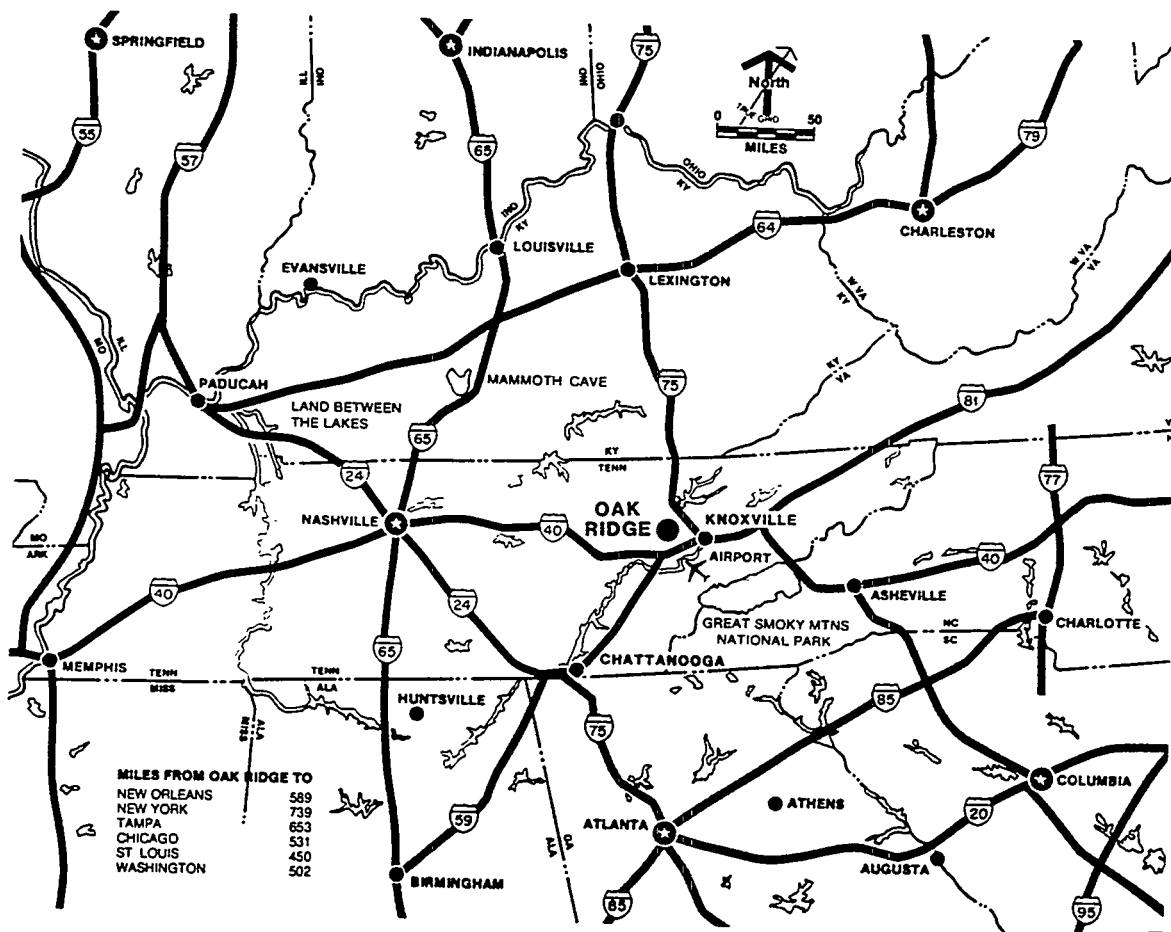


Fig. 3.1. Oak Ridge, Tennessee — Location of the Oak Ridge Gaseous Diffusion Plant

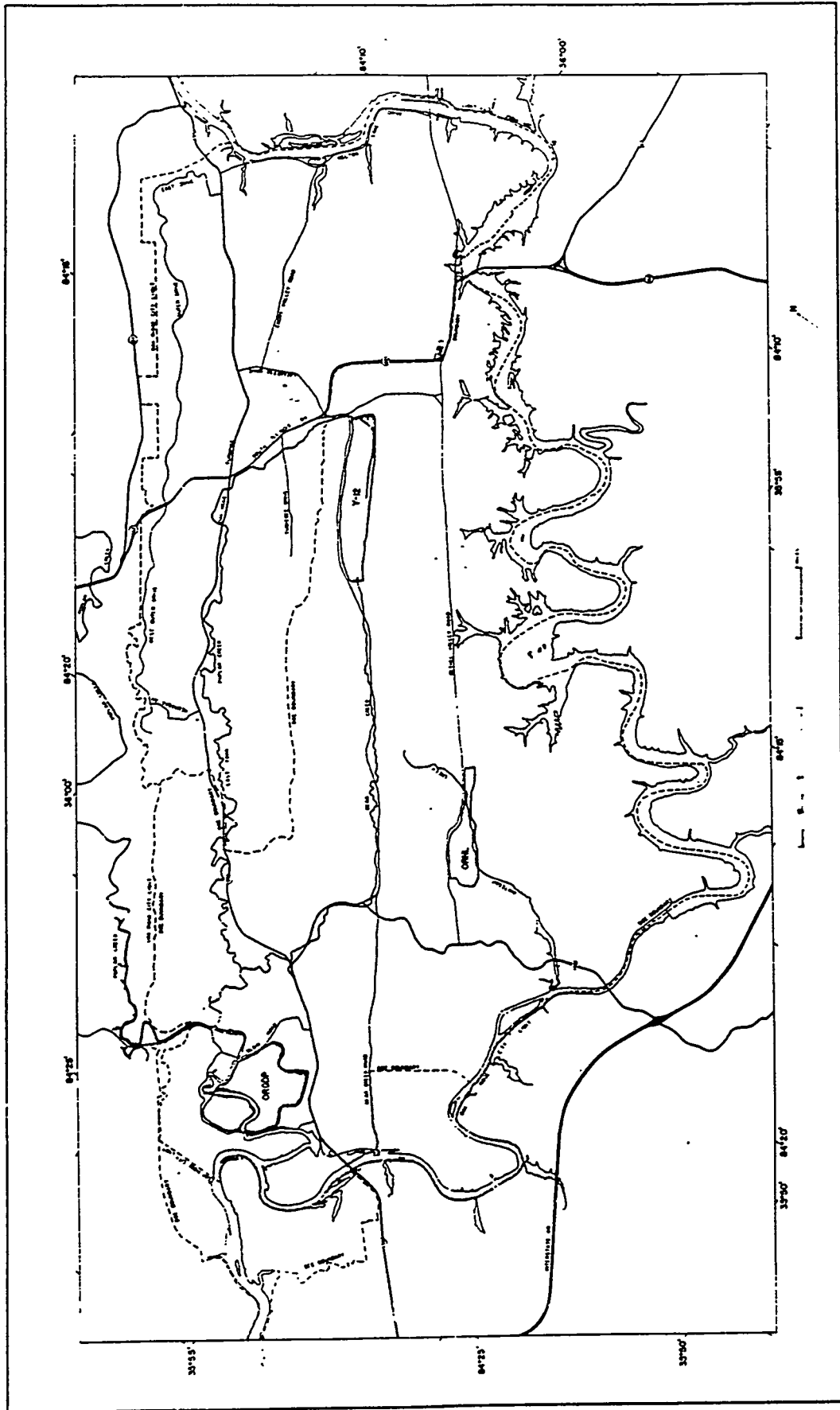


Fig. 3.2. DOE Reservation Location Map

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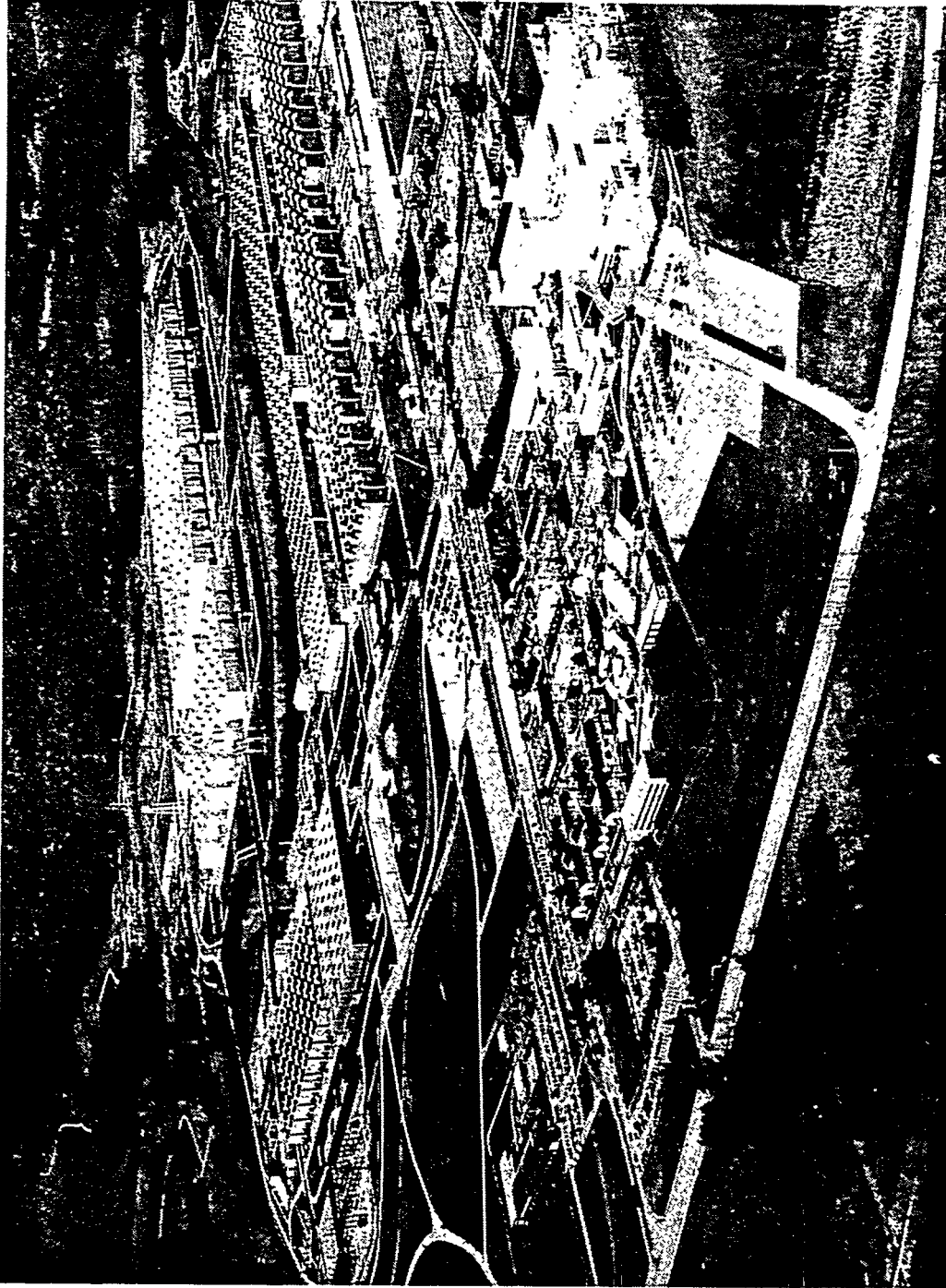


Fig. 3.3. Aerial Photo of the Oak Ridge Gaseous Diffusion Plant



170 acres on the site; the diffusion cascade process buildings on the left and the centrifuge development buildings on the right dominate the site.

#### 3.1.4 Clinch River and Tributaries at ORGDP

As shown in Figure 3.4, surface runoff within ORGDP boundaries is drained by Poplar Creek to the Clinch River which functions as the regional control waterway for both surface and groundwater for the site. Water levels on the Clinch River are regulated by TVA; fluctuations on the river can cause backflow into its tributary streams.

#### 3.1.5 Flood Map of the ORGDP

The flood map shown in Figure 3.5 illustrates the various flood plains on the ORGDP site. A description of these floods as defined by TVA is presented below:

- 100-Year Flood - The flood with a 1 in 100 (1%) chance of being equaled or exceeded in any given year.
- 500-Year Flood - The flood with a 1 in 500 (0.2%) chance of being equaled or exceeded in any given year.
- Maximum Probable Flood (MPF) - A flood which is comparable to all but the more extreme floods known to have occurred in the eastern part of the United States. The rainfall used to estimate the flood (National Weather Service Hydrometeorological Reports 41, 45, and 47) was determined by transposing to the valley without maximization all but the most extreme storms which have occurred elsewhere and is approximately 60% of the probable maximum precipitation (PMP). The resulting floods equal about 40% to 60% of the PMF for the same drainage basin.

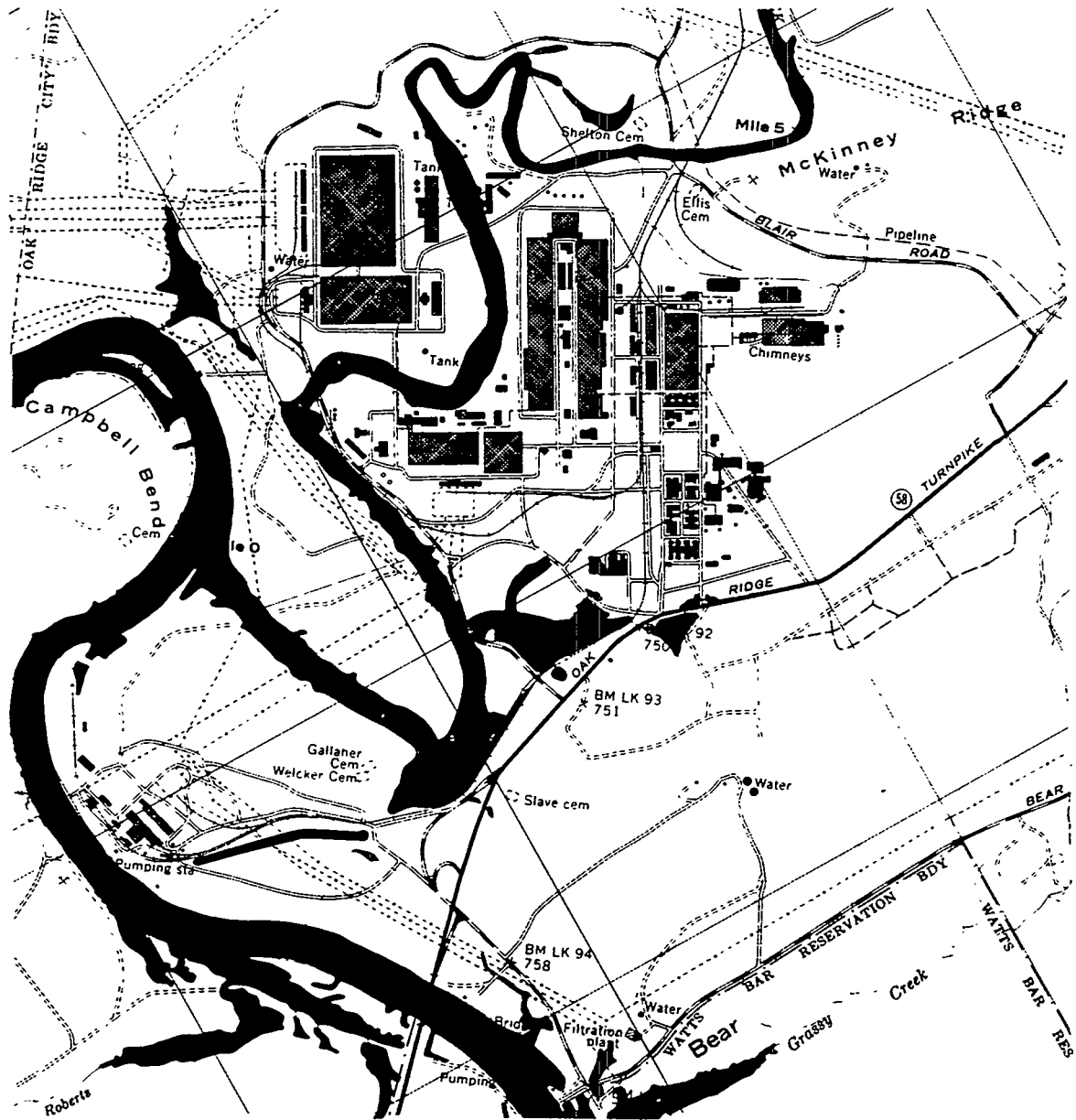


Fig. 3.4. Clinch River and Tributaries at the Oak Ridge Gaseous Diffusion Plant

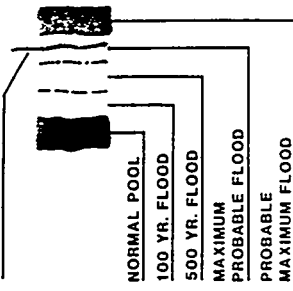
# ORGDP Site Development Plan

For The:  
U. S. Department of Energy  
Oak Ridge  
Gaseous Diffusion Plant

Prepared By:  
Union Carbide Corporation  
Nuclear Division

## LEGEND:

### STRUCTURAL PROFILE



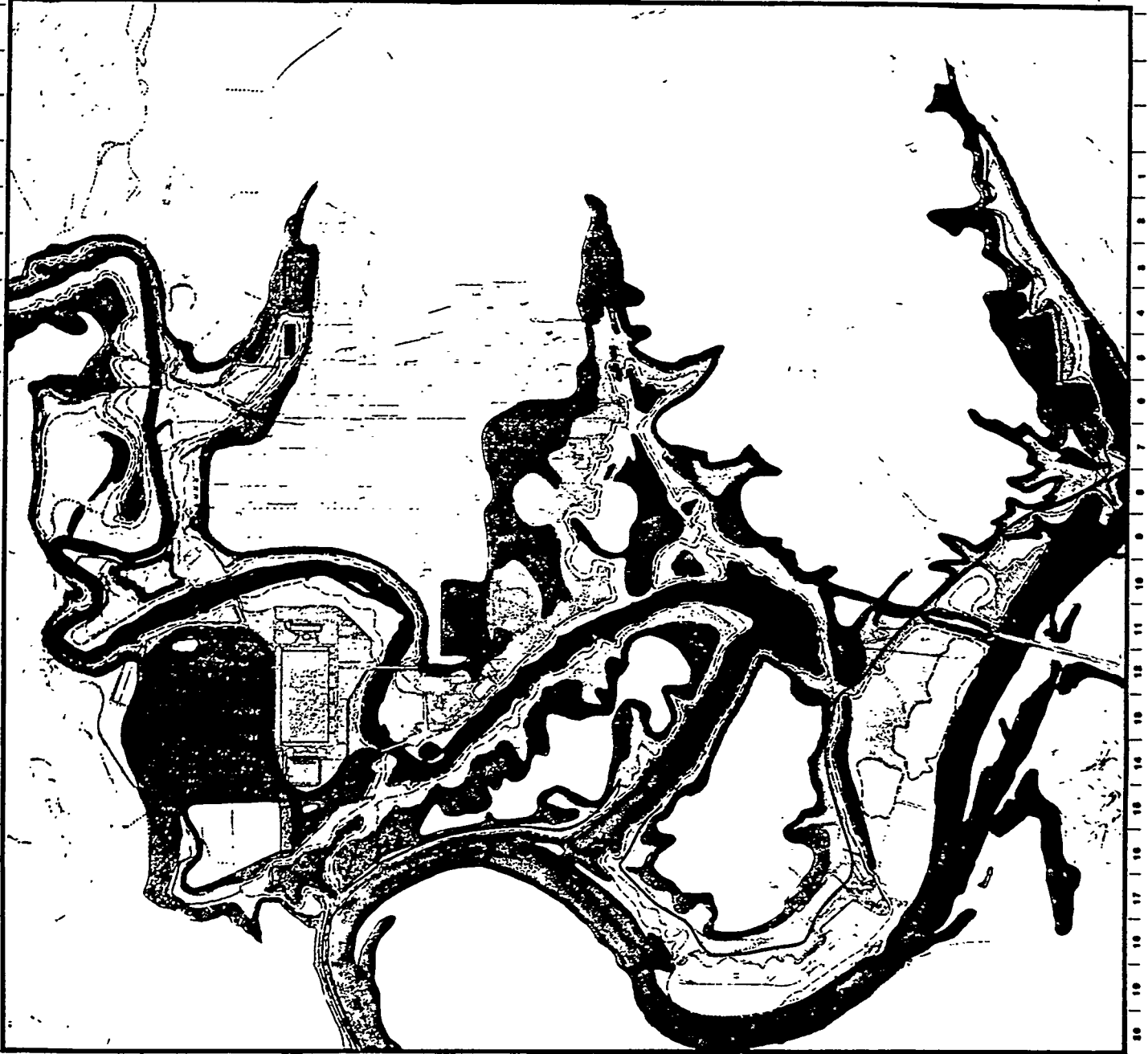
## Graphic Scale:



## TITLE:

## FLOOD MAP

DATE: March 1984  
REVISED:



- Probable Maximum Flood (PMF) - The most severe flood that can reasonably be predicted to occur at a site as a result of hydrometeorological conditions. It assumes an occurrence of PMP critically centered on the watershed and a sequence of related meteorologic and hydrologic factors typical of extreme storms.

### 3.1.6 Solid Waste Management Units Location

The location of solid waste management units (SWMUs) are identified on the map of ORGDP in Figure 3.6.

## 3.2 HISTORICAL INFORMATION

Construction of ORGDP was begun in 1943, and the first diffusion stages became operational in 1945 as the worlds first facility for large scale separation of  $U^{235}$  from  $U^{238}$ . Its initial mission was the production of enriched uranium for military applications. The first diffusion cascade of stages was followed by construction of four additional cascade buildings to provide a total of 5100 stages for the enrichment of normal uranium at an assay of 0.711%  $U^{235}$  to an enriched level of about 98%. When requirements for military applications were satisfied in 1964, the top of the ORGDP was shutdown reducing the separating stages to 1440 which limited the enrichment level of the plant to 5%. This provided the full range of enrichment assay to supply the civilian nuclear power reactors.

The first major improvements to the diffusion cascade were started in the 1950's and completed in the early 1960's. In anticipation of large demands for enriched uranium for both domestic and foreign nuclear power reactors, another major

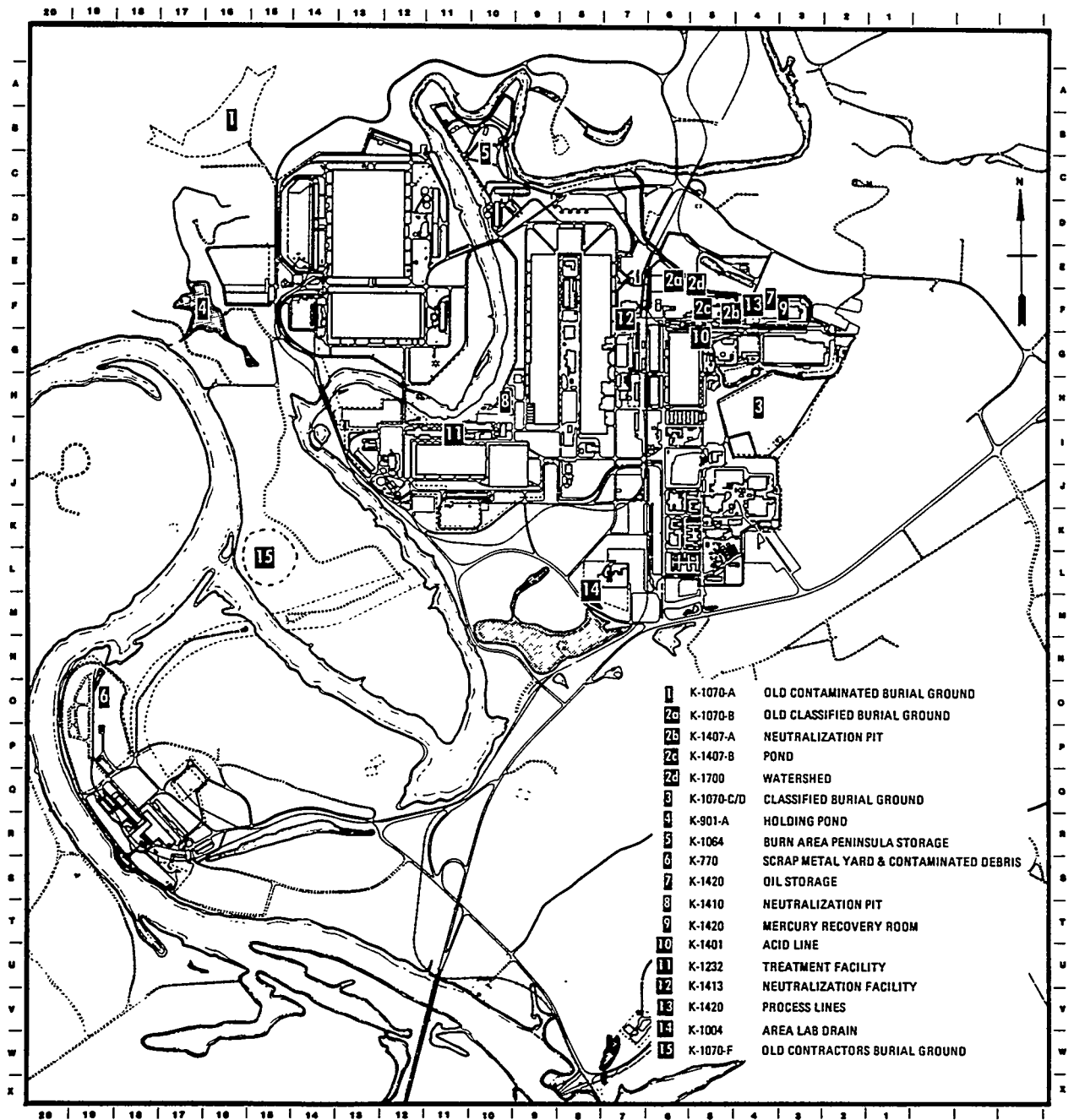


Fig. 3.6. SWMUs at ORGDP

improvement and uprating program was begun in the early 1970's and completed at ORGDP in 1981. These programs included the replacement of diffusion barriers in the stage diffuser and modifications to piping and compressors. In addition, the stage cooling capacity, the design stage operating pressure capability, and the electrical power system were uprated providing a total increase of 60% in separating capacity at a new maximum power level of 2180 MW.

In addition to a major scale research and development effort for support of the operating cascade and the Cascade Improvement and Uprating Program (CIP/CUP), the R&D efforts for developing alternatives to the diffusion process for uranium isotope separation were intensified at the ORGDP. Two processes were looked at in major programs: Gas Centrifuge Enrichment Process (GCEP) and the Atomic Vapor Laser Isotope Separation (AVLIS).

As with any large scale separation process, major support and auxiliary facilities were required for operation of the gaseous diffusion plant. Typical facilities included the feed system and the systems for collecting the product and waste (tails) streams. Since the medium for diffusion separation is a gas, the uranium hexafluoride ( $\text{UF}_6$ ) feed material was vaporized to the cascade from its containment cylinder in steam heated autoclaves. The product and tails withdrawal required a condensing system. Uranium hexafluoride is handled as a solid in large steel cylinders having the more common capacities of 5,000, 21,000, and 27,500 pounds  $\text{UF}_6$ .

Because operation of most of the diffusion stage is below atmospheric pressure, contaminant leakage to the cascade from the atmosphere, from feed materials and internal coolant leaks, required a purge cascade for its removal. Trapping facilities employing alumina and sodium fluoride were used extensively here and in other parts of the cascade.

Conversion of uranium oxide and uranium tetrafluoride to cascade uranium hexafluoride feed materials was carried out at ORGDP from 1952 to 1961. In recent years the majority of the  $UF_6$  conversion was supplied by private industry.

A massive heat dissipation system was required to dispose of essentially all of the heat equivalent to the electric power supply to the diffusions cascade; this power is used to drive the compressor and move the  $UF_6$  (in an adiabatic compression) through the process. The excess heat from the diffusion cascade was removed by a recirculating water system and then dissipated to the atmosphere by mechanical induced draft cooling towers. The recirculating water source was raw water from the Clinch River which was pumped to a clarification facility and treated with lime, soda ash, and organic coagulants for removal of calcium, magnesium, and suspended solids. The clarified water was then treated with a hexavalent chromium, zinc, and phosphate to inhibit corrosion of heat transfer equipment.

Due to high rates of water evaporation in this system, it was necessary to remove or direct a portion of the recirculating water flow through a resoftener for removal of dissolved solids

that concentrate in the water. The precipitate for this operation was discharged to a holding pond. In addition, a blowdown stream from the recirculating water system was also processed through an electrolytic reduction facility where the soluble  $\text{Cr}^{+6}$  was reduced to a trivalent state, precipitated and transferred to the same holding pond.

In addition to the gaseous diffusion process facilities, the ORGDP site also includes the following support or auxiliary facilities.

Steam Plant	Fluoride Production Plant
Nitrogen Plant	Administration Facilities
Air Plant	Sanitary Water Plant
Sewage Disposal Plant	Electrical Power Distribution
Chemical Cleaning and Decontamination	Chemical Storage Facilities e.g. $\text{UF}_6$ Cylinders
Maintenance Facilities	HF tank farm
Computer Center	$\text{F}_2$ storage
Laundry	Water Treatment Chemical
Classified Burial Ground	Metals Cleaning Facilities
Laboratories	Metals Plating Operations

Cascade Improvement Program installations, as well as regular maintenance of operating equipment, required parts cleaning and decontamination prior to handling by maintenance. Solutions were produced that required concentration and recovery with some residual discard and burial. Laboratory sample residues and obsolete chemical reagents, spent chemicals, and contaminated equipment used in research and development projects, and trapping materials such as alumina and sodium fluoride became candidates for discard (i.e., sometimes cleaned and/or buried).

The CIP/CUP program, described earlier, involved major diffuser, coolant system, piping, and instrument modifications



which produced hundreds of tons of unclassified low level contaminated scrap metal which was stored above ground in a scrap metal yard.

In addition, contaminated classified scrap and material and equipment discards and classified waste from both the diffusion plant and the centrifuge and the AVLIS R&D facilities were taken to classified yards and buried.

As the result of a sharp decline in the growth of the Nuclear Power Industry in the 1980's, it became evident that the production of enriched uranium fuel for nuclear reactors could be met with the operation of only two diffusion plants. Socio-economic studies led to the decision to place the ORGDP in standby operation; standby operation was accomplished in September 1985. At the same time it was decided to halt work at ORGDP on two other major development programs - GCEP and AVLIS. The Enrichment Technology Application Center continues to utilize a part of the centrifuge development facilities for production scale separation of isotopes for DOE laboratories, universities, and private industry. The Material Handling Demonstration Module for the AVLIS process has been placed in a standby state. The remainder of the experimental facility is being used on separation technology in a small scale research and development effort.

The current ORGDP mission is to make optimal use of DOE's Uranium enrichment investments by:

- Maintaining the restart capability of the ORGDP cascade until the decision to restart or shutdown permanently is made.
- Providing high-quality business services and technical support to the U.S. enrichment enterprise.
- Supporting the development, demonstration, and deployment of advanced enrichment technology.
- Utilizing unique uranium enrichment technologies, expertise, and facilities to support and strengthen other DOE programs and other programs of national importance.
- Providing responsible stewardship of DOE's facilities by ensuring employee health and safety, protection of the environment, and safeguarding of national security.

### 3.3 OPERATIONAL INFORMATION

#### 3.3.1 ORGDP Operation

ORGDP, now maintained in ready standby, is part of a three plant diffusion complex operated by Martin Marietta Energy Systems, Inc., for the United States Department of Energy. The other two plants are the Paducah Gaseous Diffusion Plant located at Paducah, Kentucky, and the Portsmouth Gaseous Diffusion Plant located at Portsmouth, Ohio.

Forty years of experience in operating the gaseous diffusion plant and major diffusion, centrifuge, and laser isotope development facilities has evolved a mature management organization. Essential operating, maintenance, engineering, laboratory, security, safety, health, and environmental standards and procedures have been established. Employees at the ORGDP site number approximately 2230 with an organizational breakdown presented in

Figure 3.7 to show the various divisions.

### 3.3.2 Operation of SWMUs

Some of the ORGDP SWMUs listed in Table 2.3 continue to be operated at ORGDP, while others have been closed. SWMUs that are currently in operation are described below.

1. K-1070 C/D Classified Burial Ground. The burial ground is a 22 acre tract of land that is currently in use for the burial of classified low-level radioactive and non-radioactive waste materials. Also part of the tract was used in the past for disposal of hazardous chemicals such as waste oils, solvents, laboratory quantities of corrosives, oxidizers, reducing agents and chemical containers. The disposal of hazardous chemicals at this site was discontinued in 1979.
2. K-770 Scrap Metal Yard and Contaminated Debris. This yard, covering about 30 acres, is located adjacent to the Clinch River and is estimated to contain 40,000 tons of low-level contaminated scrap metal, the majority coming from the CIP/CUP programs. Scrap metal continues to be taken to this area where a segregation program is now being carried out. Scrap metals are separated by type and are reduced in volume by shearing.
3. K-1420 Oil Storage. This solid waste management unit consists of a paved area of about 14,000 square feet where uranium contaminated lube oils are stored awaiting decontamination. An inspection reveals that residual quantities of oil have spilled or leaked onto the paved area.
4. K-901-A Holding Pond. This unit consists of a five acre surface impoundment which is used for settling chromium hydroxide precipitate generated from treating the diffusion cascade recirculating cooling water. The pond is being evaluated on the basis of effluents, sludge, and sediment data.
5. K-1401 Acid Line. This underground line is used to transport corrosive wastewater generated in the K-1401 Metals Cleaning Facility to the K-1407A Neutralization Facility. Although the leaks have been repaired and

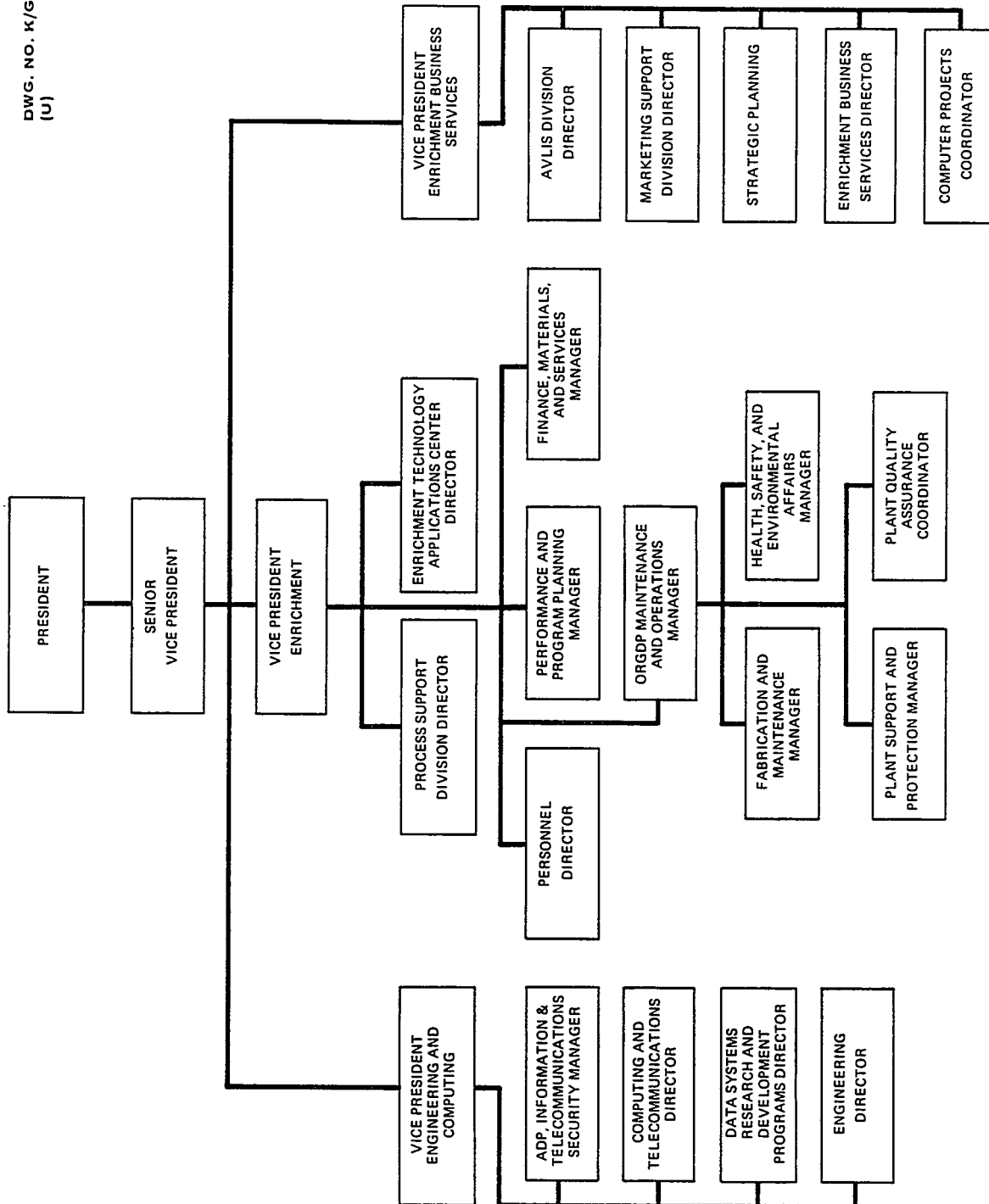


Fig. 3.7. Organizational Chart of the Oak Ridge Gaseous Diffusion Plant Site

plastic lines inserted into broken sections, it will be evaluated since it is known that hazardous chemical wastes leaked into adjacent soil.

6. K-1004 Area Drain Line. This line drains the K-1004 Lab area to the K-1007-B Holding Pond. Although there were no known breaks or leaks from this line, this unit will be evaluated since it at one time carried hazardous chemicals; these materials are now being collected and excluded from the line.
7. K-1420 Process Lines. These lines are used to transport hazardous and/or radioactively contaminated liquid solutions to the K-1407-B Holding Pond. One of the lines, abandoned and excavated in a construction project, was found to contain PCBs, mercury and uranium. Although no leaks from these lines were known, the K-1420 process lines will be evaluated as a solid waste management unit.
8. K-1232 Treatment Facility. This facility was built and previously used for the production of material for the CIP/CUP program. In 1983, it was modified for treatment of Y-12 wastewaters. The neutralization, filtering, centrifuging and pumping components of the facility are located inside the K-1232 building. Two 75,000 gallon settling basins and other neutralizing equipment are located outside. The inside facility is provided with secondary containment. A RCRA Part B permit application has been submitted for this unit.
9. K-1407-A Neutralization Pit and K-1407-B Holding Pond. Low-level contaminated waste from cleaning operations in K-1420 and K-1401, coal pile runoff, and solutions from backwash and regeneration of steam plant water softening resins are some of the wastes that may be neutralized in the K-1407-A Neutralization Pit and/or discharged directly to the K-1407-B Holding Pond. This system will continue in use and be evaluated in one of the scheduled RFI plans. A RCRA Part B permit application has been submitted for this unit.
10. K-1413 Neutralization Facility. The treatment facility consists of a 21,000 gallon underground tank used primarily as a backup facility for the K-1232 treatment facility. Presently, the tank is infrequently used for treating a shipment of Y-12 wastewater. The unit provides chemical precipitation and pH adjustment for heavy metal laden corrosive solutions.

The following is a description of past operations of SWMUs that have since been closed:

1. K-1070-A Old Contaminated Burial Ground. The burial ground was utilized for the disposal of unclassified low level radioactive solid waste and mixed chemical waste that were poured in auger holes and trenches or buried in drums. This site was opened during the late 1940's and closed in March 1976. While the total area committed for this type of disposal is approximately 2.6 acres, the area actually occupied by the buried materials is less than 0.2 acre. The bulk of the material is leached alumina containing small quantities of uranium that were generated as a waste stream from the Uranium Decontamination Facility. Small amounts of other uranium and thorium compounds, contaminated UF<sub>6</sub> cylinders, beryllium chips, boron, radioactively contaminated NaF, oil, rags, etc. are also buried at this site.
2. K-1070-B Old Classified Burial Ground. The burial ground is estimated to have been in operation from the 1960's through 1977. The burial ground covers approximately 3.7 acres and has an average depth of approximately 30 feet. Records were not maintained and the types and quantities of waste material disposed of at the unit are not known. The types of materials that are expected to be in the unit include radioactive and non-radioactive classified materials. It is also suspected that hazardous chemicals may have been disposed of at the unit.
3. K-1064 Burn Area Peninsula Storage. The unit, consisting of approximately three acres of land, was used to dispose of and store waste solvents, organics, and radioactively contaminated waste oil. The disposal operation is believed to have occurred during the 1950s and 1960's and consisted of the open burning of solvents in an open metal container. Records are not available pertaining to the quantities of material disposed of by this operation. In the late 1960's and early 1970's, the area was used to store drums of solvents, organics, including PCBs and radioactively contaminated waste oil. The records that were generated during the closeout of the unit indicate that there was 1838 drums of waste stored at the unit. These drums were removed and the unit closed during 1979.
4. K-1410 Neutralization Pit. The unit was constructed in 1975 and use was discontinued in 1979. The tank has a capacity of 15,800 gallons and was used to neutralize

corrosive solutions generated in the K-1410 plating facility.

5. K-1420 Mercury Recovery Room. The unit was operated during the 1960's for cleaning used mercury for reuse by utilizing a distillation process. Presently, the room contains the hoods, distillation equipment, and other associated equipment used in the recovery process that is suspected to be contaminated with residual quantities of mercury.
6. K-1070-F Old Contractors Burial Ground. The unit began operation in the early 1970's and was closed in 1978. The site is approximately 10 acres and was used for the burial of construction and renovation rubble including soil, concrete, asphalt, wood, and roofing materials. Although records were not kept for materials disposed of during the first few years of operation, there is no evidence that radioactive or hazardous materials were disposed of at this site.

Details on prior storage, current use, operational schedules, types of treatment, and disposals will be supplied on these active solid waste management units in the site specific RFI plans.

#### 4. CHARACTERIZATION OF THE ENVIRONMENTAL SETTING

##### 4.1 GENERAL

The ORGDP site in eastern Roane County lies in the Valley and Ridge Physiographic Province and is characterized by parallel ridges and valleys trending in a northeasterly direction. Differential weathering and erosion of folded and faulted sedimentary rocks have produced linear, flatbottomed valleys separated by parallel ridges. Ridges underlain by cherty dolomite, such as Blackoak Ridge and McKinney Ridge, which form the northern and northeastern borders of the site valley, generally have broad well rounded or rolling crests, whereas Pine Ridge, to the south, is underlain by sandstone and shale and is characterized by sharp or pointed crests.

The plant site is located at the confluence of Poplar Creek with the Clinch River. Land surface ranges from approximately 700 feet sea level, the bottom of the Clinch River, to 1,000 to 1,100 feet along the ridge crests. The majority of the plant site lies within the floodplain and terrace lands of Poplar Creek where relief rarely varies more than 25 feet, with slopes averaging 1 percent.

##### 4.2 SUBSURFACE GEOLOGY

###### 4.2.1 Soils

The soils at ORGDP are primarily made up of Colbert, Nolichucky, and Talbott series of soil classes. Soils of the



Colbert series are the heaviest textured soils in the country. They are developed from highly clayey limestones, and, like the Talbott soils, occupy floors of the interrridge valleys that are underlain by limestone. The thickness averages about 15 inches. External drainage is good in most places, but internal drainage is rather poor, owing chiefly to the heavy plastic and impervious character of the subsoils. In general, the reaction is strongly acid. The native vegetation consists chiefly of deciduous trees, with some cedars. These soils differ from the Talbott soils in that they are developed from the residuum of a more argillaceous limestone, are shallower over bedrock, have tougher, stickier, and more tenacious subsoils, are more poorly drained internally, and have more gray and yellow and less red in the subsoils. Outcrops of limestone are common.

Soils of the Nolichucky series occupy the older higher lying terraces. The alluvium giving rise to these soils originated chiefly from sandstone and shale and has lain in place long enough for well-developed soil profiles to have formed. These soils have yellowish-gray or brownish-gray surface soils and yellowish-red subsoils. They resemble the Waynesboro soils but differ from those soils principally in having lighter colored surface soils. The Nolichucky soils are friable, are strongly acid in reaction, are low in organic matter, have good tilth conditions, are medium to low in fertility, and are medium to low in productivity. They range from undulating to rolling in relief, the slope ranging from about 2 to 15 percent. These

soils do not cover a large area and occur chiefly along the rivers.

Soils of the Talbott series occupy undulating, rolling, and hilly areas in the troughs of the interridge valleys, mainly in association with the Colbert and Dewey soils. The Talbott soils are developed from the residuum of clayey limestones and have grayish-brown surface soils and yellowish-red subsoils. The conspicuous features of the subsoils are their toughness, plasticity, and stickiness. They are well drained externally and fairly well internally. In uneroded fields, soils of the Talbott series have grayish-brown soft and friable silty clay loam surface soils about 5 to 7 inches thick. The subsoils, ranging in thickness from about 20 to 24 inches, are yellowish-red, tough, sticky, and plastic silty clay that has a fairly well defined angular nutlike structure. The substratum resembles the subsoils but differs primarily in containing numerous yellow, gray, red, and brown mottlings and in having larger structural aggregates. The substratum continues to the uneven floor of the bedrock, which lies at an average depth of about 5 feet below the surface. The bedrock is argillaceous limestone lying in strata that generally have a slight dip.

#### 4.2.2 Hydrology

A variety of rock types underlie the ORGDP area. Differences in the lithology, mode of deposition, and manner of weathering all affect the movement of water through the various

formations. Although the initial permeability of the limestone, dolomite, and shale that comprise the bedrock was low, geologic events subsequent to their formation have developed zones of secondary permeability of solution, fracturing, and weathering that control the flow of groundwater.

The surficial aquifer is made up of all the unconsolidated material overlying bedrock and consists of man-made fill, alluvium, and the residuum of weathered bedrock. The depth to unweathered bedrock varies from less than 10 to more than 50 feet depending on the weathering characteristics of the underlying rocks. Much of the fill material consists of construction debris, pieces of concrete and wood, and excavated weathered shale, limestone, and chert mixed with clay. Alluvium is present along the shores of the Clinch River and, to a lesser extent, along Poplar Creek.

Unconsolidated weathered residuum overlies bedrock throughout the area except in scattered rock outcrop areas and is generally clay structured in nature with a varying content of silt, sand, and rock fragments. With increasing depth, the clay gives way to weathered rock that has retained its structural characteristics. Bedding and joint surfaces usually exhibit some type of oxide staining. The transition from weathered rock to fresh bedrock typically occurs through an interval of less than 10 to about 30 feet.

The consolidated rock formations in the area are Cambrian to Ordovician shales, dolomites, and limestones. These strata have

been classified into groups and formations based on age, lithology, and fossil content. From oldest to youngest, the geologic units are the Rome Formation, the Knox Group, and the Chickamauga Limestone.

The Rome Formation is a sequence of interbedded sandstones, siltstones, and shales of variegated olive, maroon, and drab colors. Buff-colored sandstone ledges of the upper Rome Formation occur from Pine Ridge along the southern border of the plant area (Figure 4.1). Groundwater movement in the Rome Formation is restricted to fractures in the shales and sandstones.

Dolomite of the Knox Group is dense and commonly silicified. These relatively resistant rocks comprise Blackoak Ridge along the northern site of the plant area, as well as McKinney Ridge to the northeast. These upper Cambrian to lower Ordovician rocks consist of gray to blue-gray, thin to thick-bedded dolomite with interbeds of limestone. Soils derived from Knox dolomites are commonly reddish-orange, clay structured, and contain an abundance of chert fragments.

Solution features such as sinkholes and caverns are common in the Knox Group and are an important route for groundwater flow. Rapid movement of groundwater through these channels is an important source of many large springs. The Knox Group was exposed to erosion for a period prior to deposition of the overlying Chickamauga limestone, and the contact between the two units is a common zone of discharge for springs in many parts of the Valley and Ridge Province.

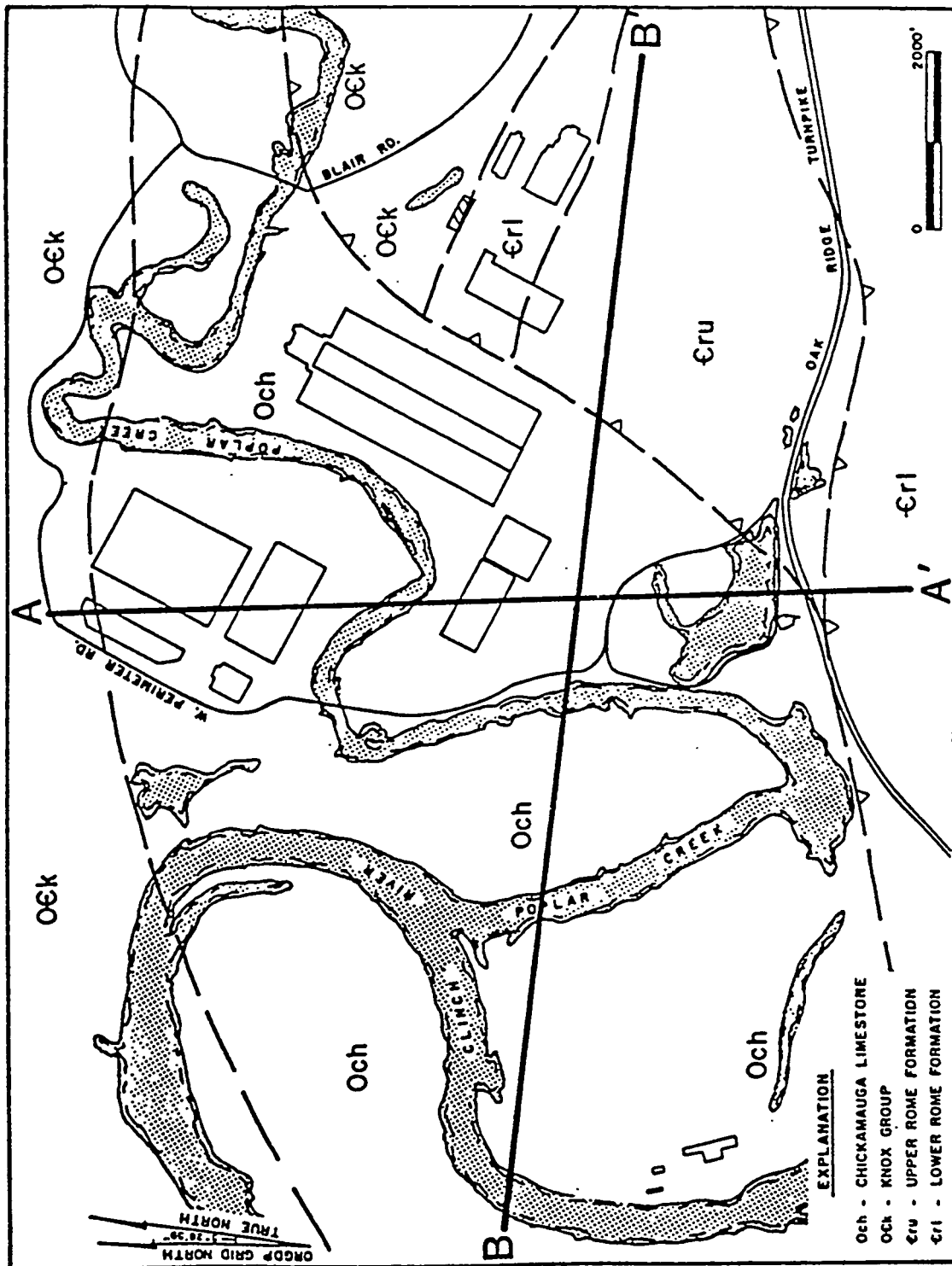


Fig. 4.1. Geologic Map of the ORGDP Area Showing Locations of Sections A-A' and B-B'

The Chickamauga Limestone, of Ordovician age, disconformably overlies the Knox dolomite and is the most extensive bedrock unit underlying the plant area. The limestone varies in character but is generally an argillaceous nodular limestone, thin bedded with intercalations of silty limestone and shale. Weathering of the shale partings permits groundwater circulation along the bedding planes and consequent dissolution of the limestone. The shale beds restrict groundwater flow across bedding, resulting in concentrated flow along the limestone-shale contact with resultant solution cavities. The cavities form conduits for accelerated flow and are a common source of spring discharge from the Chickamauga Limestone.

The dominant structural feature in the plant area is the Whiteoak Mountain thrust fault which trends northeasterly across the southern border of the plant, roughly parallel to Oak Ridge Turnpike (Figure 4.1). The Whiteoak Mountain fault is actually a zone of faulting, in which a number of separate fault slices have juxtaposed various geologic units. In the plant area, rocks of the Rome formation have been thrust over the younger Knox Group and Chickamauga limestone to their present position along the southern border of the area (Figures 4.1 and 4.2). This movement was part of a regional tectonic activity that resulted in the present structure of the Valley and Ridge Province.

A low-angle fault diverges from the Whiteoak Mountain fault and trends in a northerly direction across the plant area, truncating the east-trending faults which it apparently post-

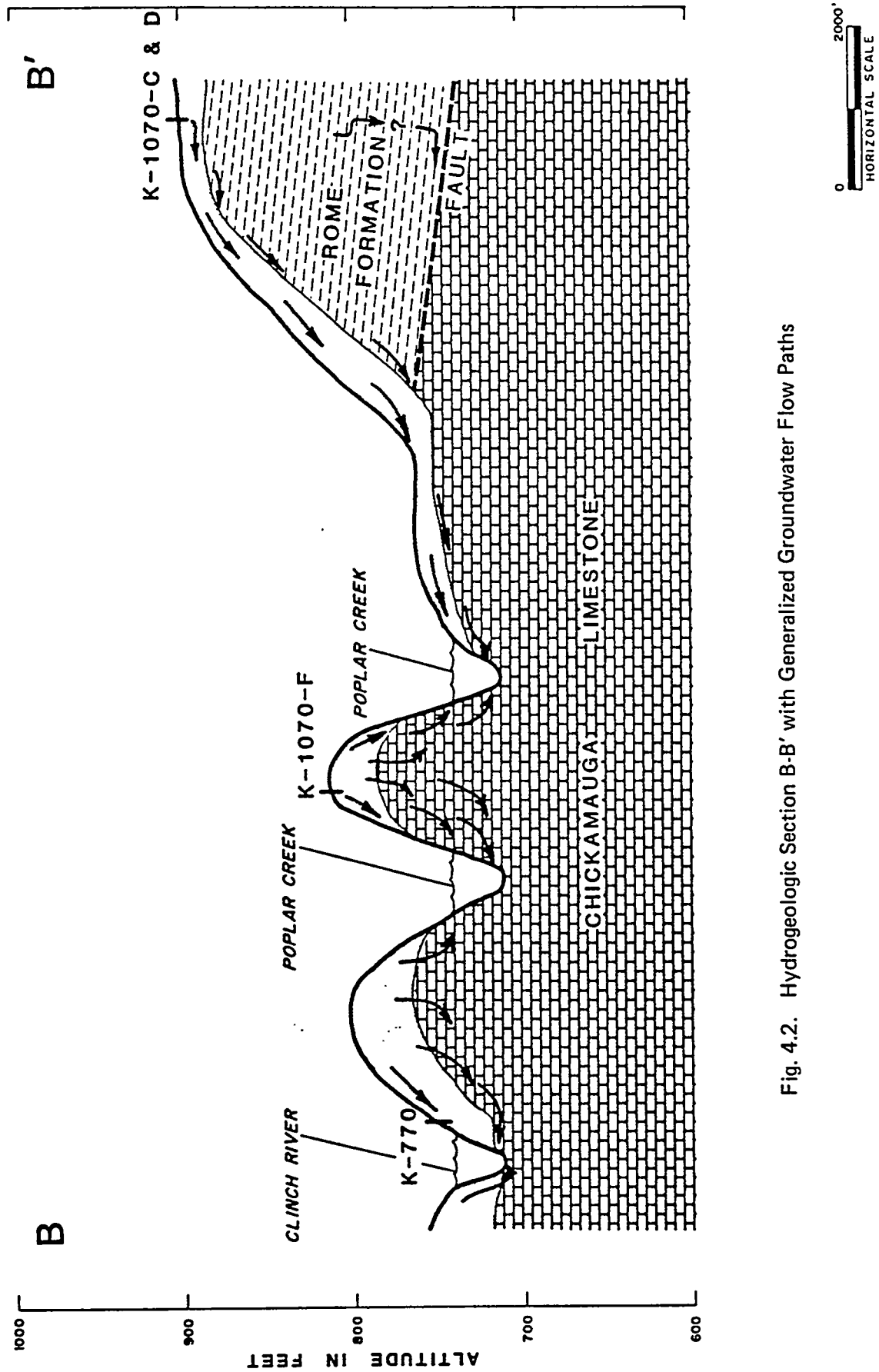


Fig. 4.2. Hydrogeologic Section B-B' with Generalized Groundwater Flow Paths

dates. The effect of these faults on the groundwater system has not been determined in any detail, although it is presumed that increased weathering of rocks along the fault planes may, in some cases, develop paths of preferential flow (Figure 4.3).

The presence of joints (fractures) in the rocks is one of the most important factors controlling the movement of groundwater. Joints provide pathways that may become enlarged by solution in the carbonate rocks, or in the case of a shale or well-cemented sandstone, may allow the movement of groundwater through otherwise impervious strata. Studies of joints in nearby areas indicate that joint orientation and spacing are quite variable. The studies generally agree that there is at least one major joint set that roughly parallels the geologic strike and dips 40 degrees to the northwest. A second steeply-dipping joint set strikes about N12°W.

Joint spacing may vary from fractions of inches to several feet. The greatest concentration of joints are observed in siltstones and cemented sandstones, the least in shales and limestones. Joint density is inversely proportional to bed thickness in both shales and siltstones, thus the thinly-bedded Rome and Chickamauga rocks are host to many closely-spaced joints that are a principal path of groundwater movement.

The size of joint openings is greatest in the weathered zone and diminishes rapidly with depth. Brittle rocks, such as limestones, siltstones, and carbonates, are more common hosts to joints than ductile rock such as shale.



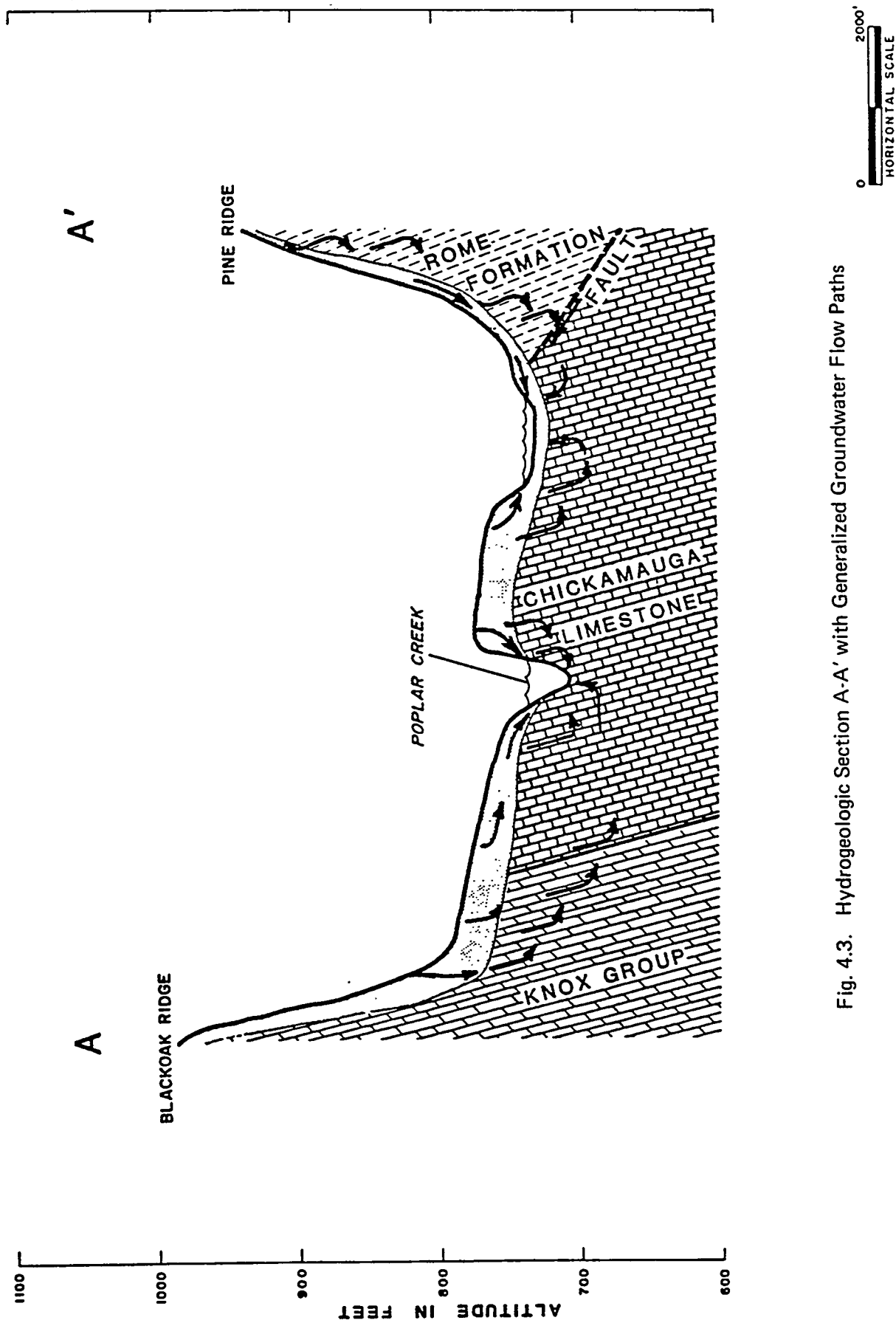


Fig. 4.3. Hydrogeologic Section A-A' with Generalized Groundwater Flow Paths

Local recharge from precipitation moves along relatively short flow paths from the areas of infiltration downgradient to the areas of seepage or springflow into the banks and bottom of the nearest reach of Clinch River or Poplar Creek. The relatively moderate relief of the area provides insufficient hydraulic head for deep groundwater circulation, and the bedrock lithology, geologic history, and regional structure do not appear to provide deep permeable zones for groundwater flow beyond the local system.

The surficial aquifer can be considered as a single, though complex unit. The unconsolidated material is relatively homogeneous and groundwater flow is generally predictable; that is, flow is downgradient, normal to the contours on the water table. Contours of the water table and groundwater flow lines, inferred from water levels in 40 wells, toward Poplar Creek, and Clinch River are shown in Figure 4.4. In areas where well data are limited, interpretation is augmented by judgment based on topography and on known or inferred hydrologic characteristics such as permeability.

Groundwater gradients are generally low throughout most of the plant area, due to the subdued nature of the topography. This fact, coupled with the relatively low permeability of most of the surficial material ( $10^{-5}$  to  $10^{-4}$  cm/sec), results in extremely slow velocities of groundwater flow, on the order of  $10^{-4}$  feet per day. Deviations in flow due to anisotropy are thought to be highly variable in this aquifer and it is likely

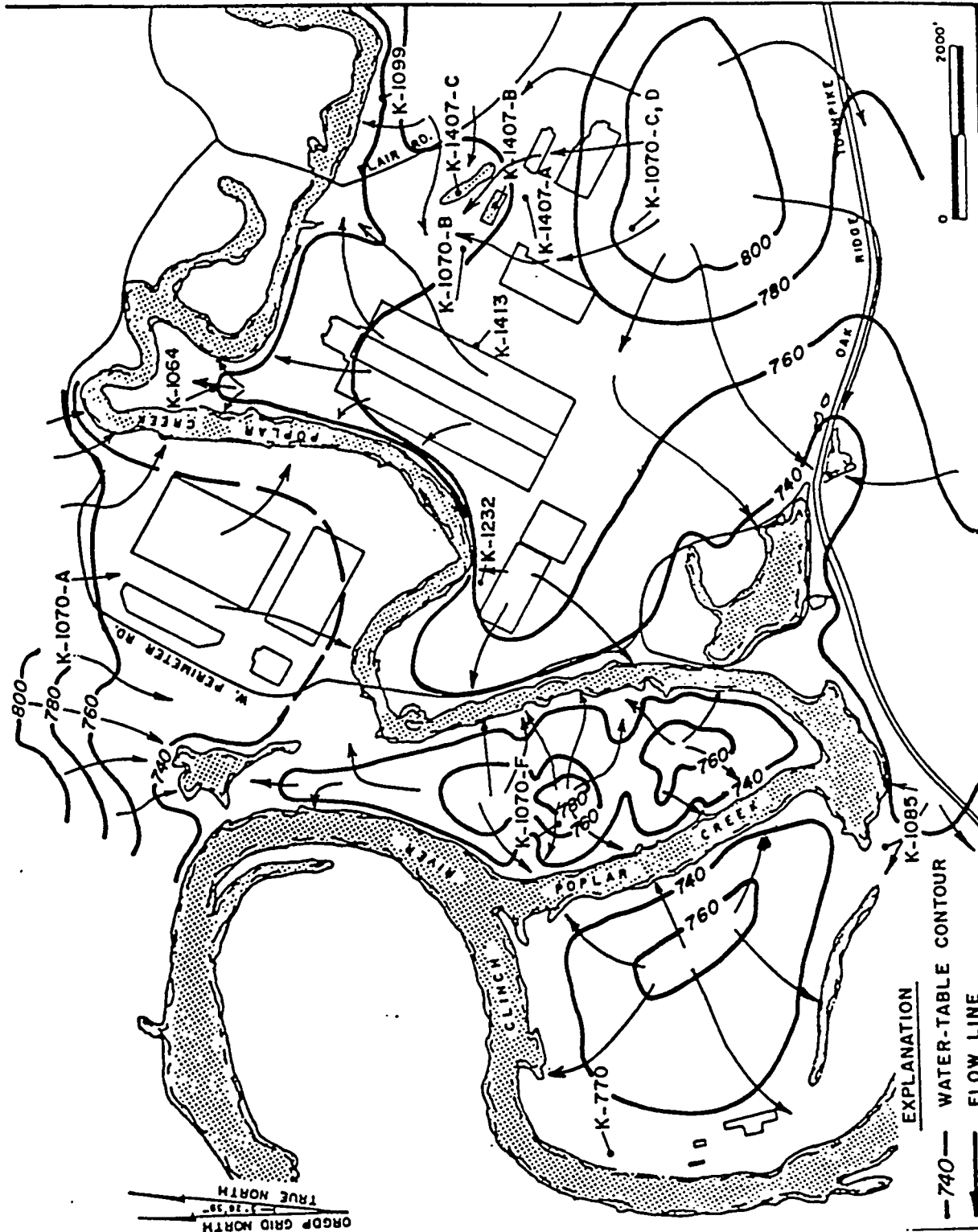


Fig. 4.4. Contours on the Water Table and Inferred Groundwater Flow Paths in the Uppermost Aquifer, ORGDP Area

that the groundwater moves in an angular pattern across the steeply-dipping bedding planes at fractures and then along the direction of the regional strike. The flow lines in Figures 4.2 and 4.3 indicate schematically the presumed flow routes in bedrock aquifers.

The contours and flow lines of Figure 4.4 describe the hydrologic situation in the uppermost aquifer. At several sites, wells are installed in the bedrock aquifer to determine the head relationship between the two aquifers and the potential for interaquifer flow. At one site for example, the potentiometric surface of the Knox dolomite aquifer was found to be several feet below the water table. Thus, the potential exists for downward movement of water from the surficial to the dolomite aquifer.

At other places at the ORGDP site, the head relation probably reverses and water moves upward from the dolomite into the surficial aquifer and the Clinch River. At other sites, particularly those underlain by the poorly permeably Rome formation, it appears that the weathered bedrock aquifer is continuous with the uppermost aquifer.

#### 4.3 SURFACE WATER

Water is drained from the ORR by a network of small streams that are tributaries to the Clinch River. At Kingston, Tennessee, the Clinch drains into the Tennessee River, which is the seventh largest river in the United States (See Figure 4.5). The

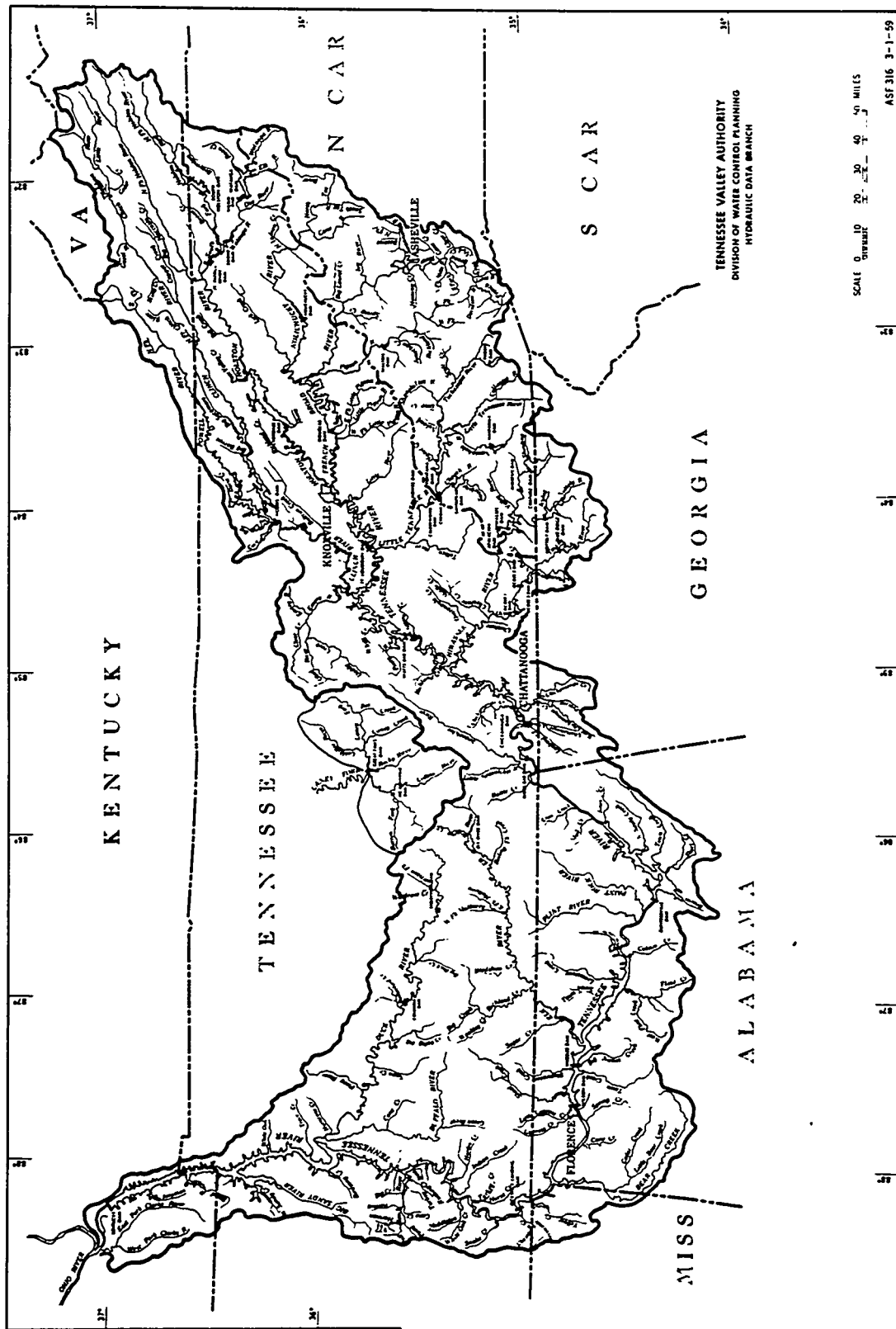


Fig. 4.5. Tennessee River Basin

Clinch River is the regional control of water flow, both ground and surface, from the reservation. Water levels on the Clinch River are regulated by the Tennessee Valley Authority (TVA), and fluctuations on the river have an impact on the tributary streams and creeks draining the reservation.

The ORR is bounded on the south and west by a 63-km (39 m) stretch of the Clinch River. Melton Hill Dam is located on the Clinch River at Clinch River Kilometer (CRK) 37.2 (CRM 23.1), forming the Melton Hill Reservoir. Several major embayments bound the reservation. The ORGDP drains predominantly into Poplar Creek (See Figure 4.6).

The Clinch River has its headwaters near Tazewell, Virginia, and empties into the Tennessee River at Kingston, Tennessee. The Clinch watershed comprises 11% of the Tennessee River Watershed.

Three dams operated by the TVA control the flow of the Clinch River. The Norris Dam built in the 1930s is approximately 50 km (31 m) upstream from the ORR. The Melton Hill Dam, completed in 1963, controls the flow of the river near the reservation. Its primary function is not flood control but power generation. Watts Bar Dam is located on the Tennessee River, but it affects the flow of the lower reaches of the Clinch.

The average discharge at the Melton Hill Dam between 1963 and 1979 was  $150 \text{ m}^3/\text{s}$  (5280 cfs). The average summer (June to September) discharge was  $134 \text{ m}^3/\text{s}$  (4720 cfs). The maximum reported discharge for the dam is  $1215 \text{ m}^3/\text{s}$  (42,900 cfs). Power is not constantly generated at the Melton Hill Dam, so water flow

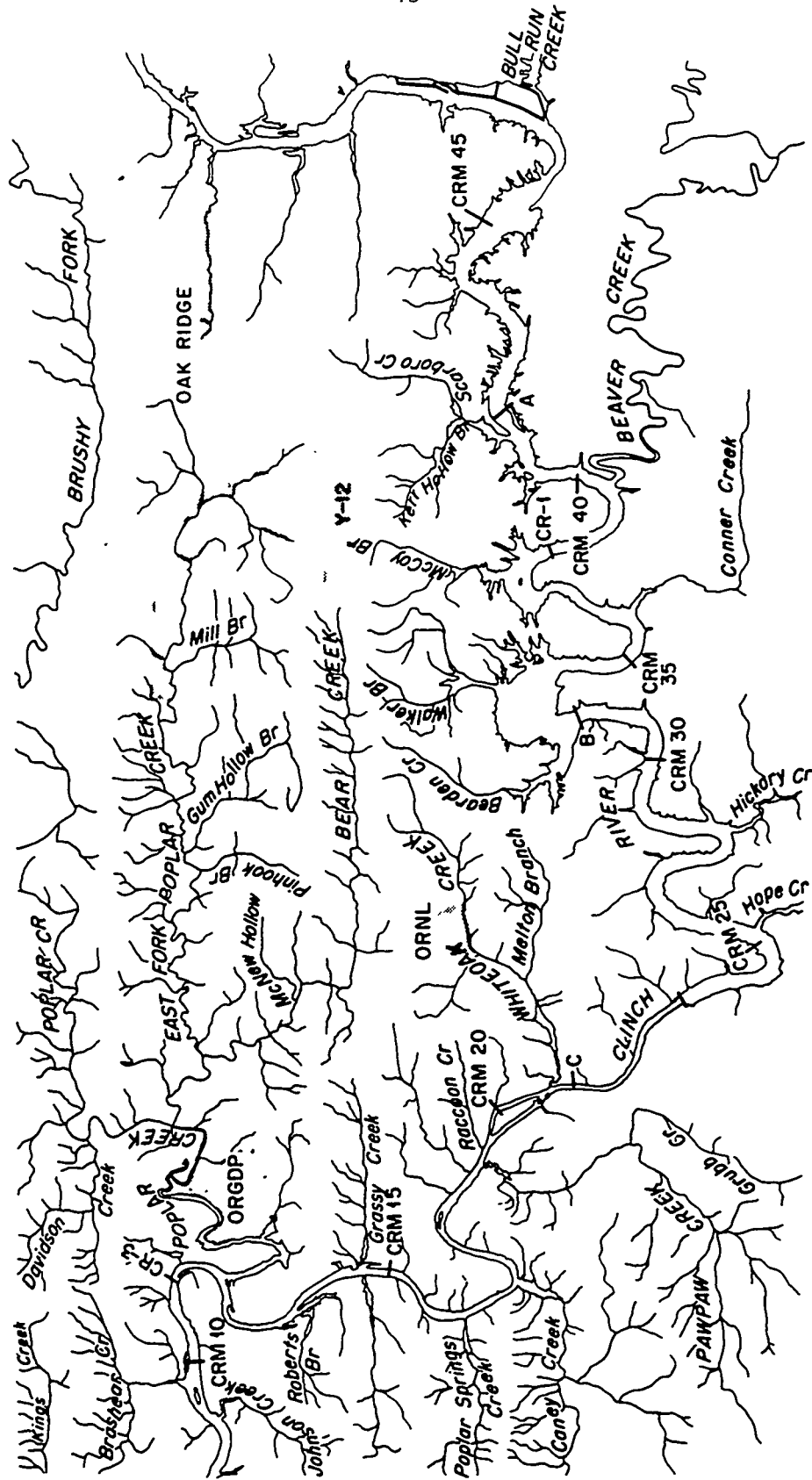


Fig. 4.6. Surface Waters of the Oak Ridge Area

in the Clinch is pulsed. Periods of zero flow are followed by hours of flow up to about  $560 \text{ m}^3/\text{s}$  (20,000 cfs). Pulsation of flow in the Clinch affects the tributaries on the reservation. Periods of no flow over the dam have lasted as long as 29 days, and the average number of days of no flow per year is 13. During flood conditions, water velocities may be hazardous and may reach  $2.1 \text{ m/s}$  (7 ft/s).

Bear Creek drains an area of approximately  $19.2 \text{ km}^2$  (7.4  $\text{mi}^2$ ). At the gaging station, the drainage area is  $18.5 \text{ km}^2$  (7.15  $\text{mi}^2$ ). Approximately 65% of the drainage basin is wooded, and the rest is primarily abandoned pasture. The headwaters of Bear Creek are at the Y-12 facility. Bear Creek does not drain the main site of Y-12, but does drain the waste disposal and refuse areas. The creek flows east down Bear Creek Valley (primarily underlain by Conasauga group) and then flows north, where it empties into East Fork Poplar Creek at EFPC 2.36 (EFPCM 1.47). The drainage pattern is a good example of trellis drainage patterns typical of the Valley and Ridge Province.

East Fork Poplar Creek (EFPC) drains an area of about  $77.7 \text{ km}^2$  (30  $\text{mi}^2$ ), including most of Y-12 and a portion of the city of Oak Ridge. The headwaters of the creek are at the Y-12 plant, where flow is controlled by New Hope Pond, a small [ 2 ha (5.0 ac)] settling basin on the east side of the plant. The average gradient along EFPC is about  $4 \text{ m/km}$  (21 ft/mi). Channel width varies along the creek's course from 3-4.6 m (10-15 ft) near Y-12 to 7.6 m (25 ft) farther downstream.



EFPC empties into Poplar Creek at PCK 8.8 (PCM 5.47) after traversing East Fork Valley. The valley is underlain by Chickamauga Limestone, but a large portion of the basin is underlain by the Knox Dolomite. Flow in EFPC is augmented by about 0.34-0.68 m<sup>3</sup>/s (12-24 cfs) of wastewater from Y-12 and 0.08-0.28 m<sup>3</sup>/s (3-10 cfs) of water from the sewage treatment plant of the city of Oak Ridge.

Poplar Creek has the largest drainage basin of any stream on the ORR [352 km<sup>2</sup> (136 mi<sup>2</sup>)]. The western half of the basin lies in the Cumberland Mountains of the Appalachian Plateau and the eastern half is in the Valley and Ridge Province. Of all the basins in the ORR area, the Poplar Creek basin has the greatest topographic relief. The elevation at the western drainage divide is 975 m (3200 ft) above MSL; where Poplar Creek enters the Clinch at CRK 19.3 (CRM 12.0) the elevation is 224 m (735 ft) above MSL.

Approximately 65% of the basin is wooded, with the remainder predominately cultivated or pasture. Most of the Poplar Creek basin is underlain by shales and sandstones that yield little water. A small portion of the basin is underlain by the highly productive Knox Dolomite.

Although the entire Poplar Creek drainage basin does not lie within the ORR, it does receive drainage directly from the ORGDP and indirectly from Y-12 via EFPC. The gaging station for Poplar Creek is at its mouth; therefore, water from all parts of the drainage basin is monitored. Coal mining on the Cumberland

Plateau affects water quality at the monitoring station. As well as having the largest basin, Poplar Creek also has the greatest flow.

Water quality in reservation streams is affected by wastewater discharges and by groundwater transport of contaminants from land disposal of waste. Though bedrock characteristics differ somewhat among the watersheds of these streams, the observed differences in water chemistry are not attributed to geologic variation but to different contaminant loadings. For example, East Fork Poplar Creek shows higher levels of several substances than any other stream, probably reflecting the influence of effluents from the Y-12 plant and from the city of Oak Ridge's municipal wastewater treatment facility. Quality of water in the Clinch River is affected by reservation activities, by contamination introduced upstream of the reservation, and by flow regulation at TVA dams.

Several institutions routinely monitor water quality in the Clinch River. Both TVA and the USGS monitor water quality just below Melton Hill Dam. The Tennessee Department of Health and Environment maintains a monitoring station at CRK 16.3 (3.2 km below the mouth of Poplar Creek and ORGDP). Martin Marietta also conducts monitoring at the above locations and at the Kingston water intake on the Tennessee River near the confluence with the Clinch River, CRK 18.5 (ORGDP cooling water intake), and CRK 23.3 (ORGDP process and potable water intake).

Background groundwater quality for the ORR region is

good and is suitable for drinking water without treatment. Groundwater on the ORR is of a calcium-bicarbonate type and generally has low total dissolved solid content. Chemistry of shallow groundwater is very similar to the chemistry of surface waters. Chemistry will change with increased depth, but limited data are available on deep groundwater quality. Actual groundwater quality may vary greatly both between and within geologic formations.

Most industries and public water supplies depend on surface water sources, but most household supplies in the region depend on groundwater. Individual wells are abundant, with most lying south of the Clinch River. The average well yield in the area is less than or equal to 0.5 liter per second (10 gpm); wells completed in solution or fracture zones may yield more, but few wells yield greater than 3.1 liters per second (50 gpm). Groundwater is not widely used for water supply purposes by the facilities on the ORR.

Groundwater contamination is a concern on the reservation. The problem is promoted by using land underlain by shallow groundwater (most valleys on the reservation) and because direct conduits to groundwater are common (such as solution features or fractures). Contamination is associated with waste disposal facilities, buried pipelines, and accidental spills.

Some groundwater quality problems exist on the ORR, but the probability of groundwater flow from the reservation to wells off the ORR is believed to be very low. This is because deep

groundwater flow is limited, and little underflow is likely to occur beneath the Clinch River, which surrounds most of the ORR.

#### 4.4 AIR

Wind roses generated from measurements made during both lapse and inversion conditions in all seasons for the ORGDP area are given in Figure 4.7. More specific atmospheric dispersion characteristics can be deduced from data on the joint frequency distribution of wind direction, wind velocity, and atmospheric stability.

These data indicate a pronounced bimodal wind-direction pattern which consists of prevailing up-valley (southwest and west-southwest) and down-valley (northeast and east-northeast) flow. This type of wind regime reflects the topographic orientation of the Valley and Ridge Province. The stability characteristics of these two directional channels are also nearly identical and represent the critical dispersion conditions. However, the similar up- and down-valley flows are probably caused by two different meteorological circumstances. The down-valley draft, identified with drainage or gravitational flow down local slopes and the broader Tennessee Valley, prevails during the inversion conditions of late evening through midmorning, whereas regional or synoptic pressure patterns dependent on solar inputs are very weak. However, in the daytime lapses, upvalley flow results when the regional or synoptic flows aloft become sufficiently strong to dominate the opposing local, down-valley,

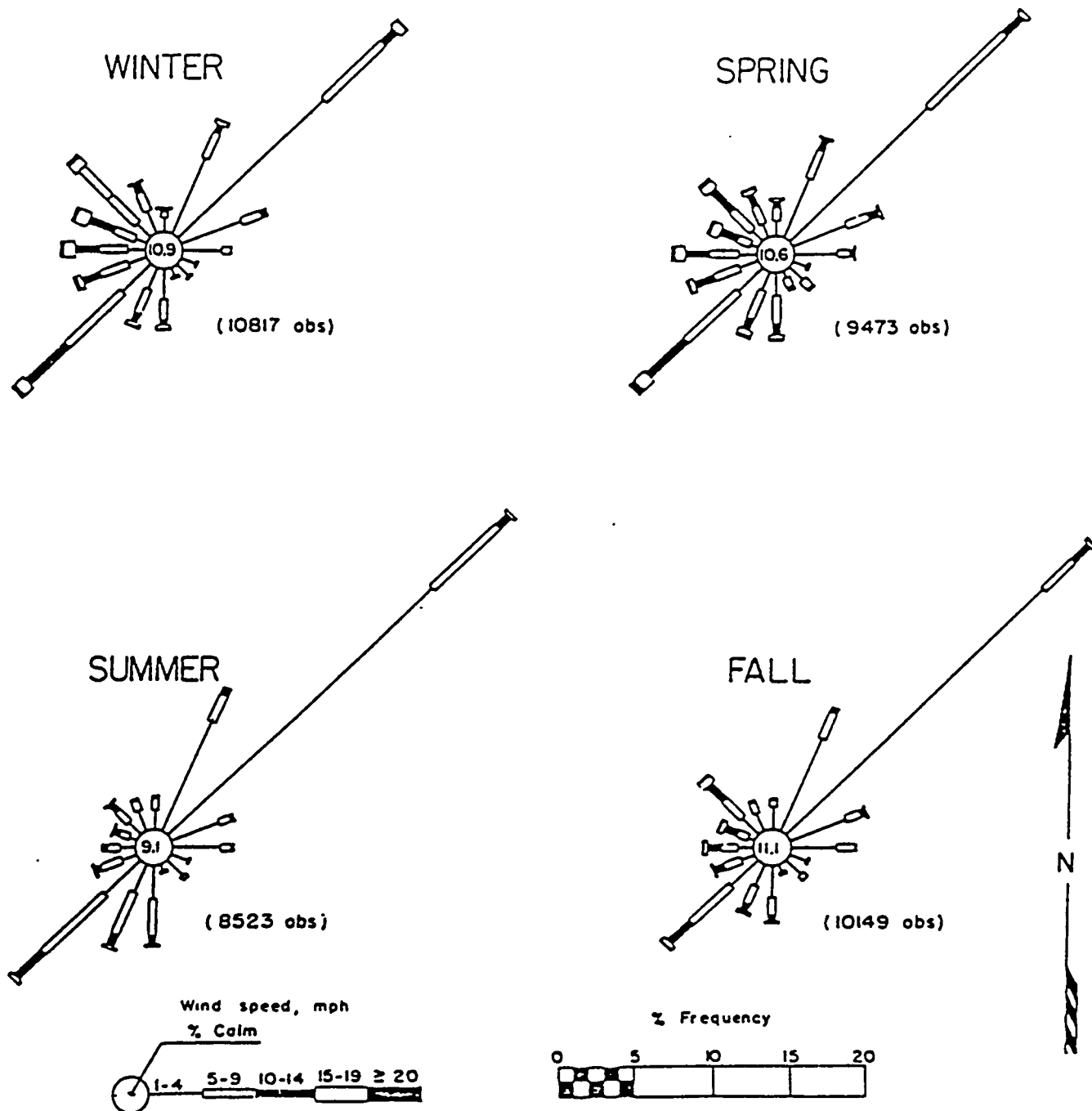


Fig. 4.7. Wind Roses for the ORGDP Weather Station, Lapse and Inversion Conditions, Combined by Season by Season, 1956-1960. Source: W. F. Hilsmeier, *Supplementary Meteorological Data for Oak Ridge*, ORO-199, U.S. AEC Oak Ridge Operations, Oak Ridge, Tenn., Mar. 15, 1963, p. 41.

gravitational winds. Since these higher regional winds do not exert as pronounced an influence on valleys, the local valley wind regime may even maintain its structure and flow in a direction opposite to that of the regional wind tracts.

The opposing forces of regional and local winds counteract one another to yield a rather high occurrence of calm periods (23 percent) and the lowest wind velocity classes (1 to 3 mph, 28%; 4 to 7 mph, 26%). In fact, the average wind speed for the Oak Ridge area is only 4.4 mph, and severe windstorms are notably rare. A major factor in the stability of air movement is the Cumberland Plateau, which diminishes the force of winter and early-spring storms. As is the case in rainstorms, local irregular ridges further minimize wind impact. The peak gust of record on the reservation is 95 km/hr (59 mph), and the probable occurrence rate of gusts of tornadic proportion is only once in every 91,000 years. Tornadoes in the southeastern states in the past half century have been of small scale and short path length and have caused only minor damage.

Atmospheric concentrations of pollutants in the vicinity of ORGDP are monitored by a network of ambient air sampling stations. The samples collected from these stations provide a method for determining the concentrations of radioactive and nonradioactive constituents in the air. The radioactive emissions are monitored at five locations around the plant facility (See Figure 4.8).

The maximum concentrations of suspended particulates were in

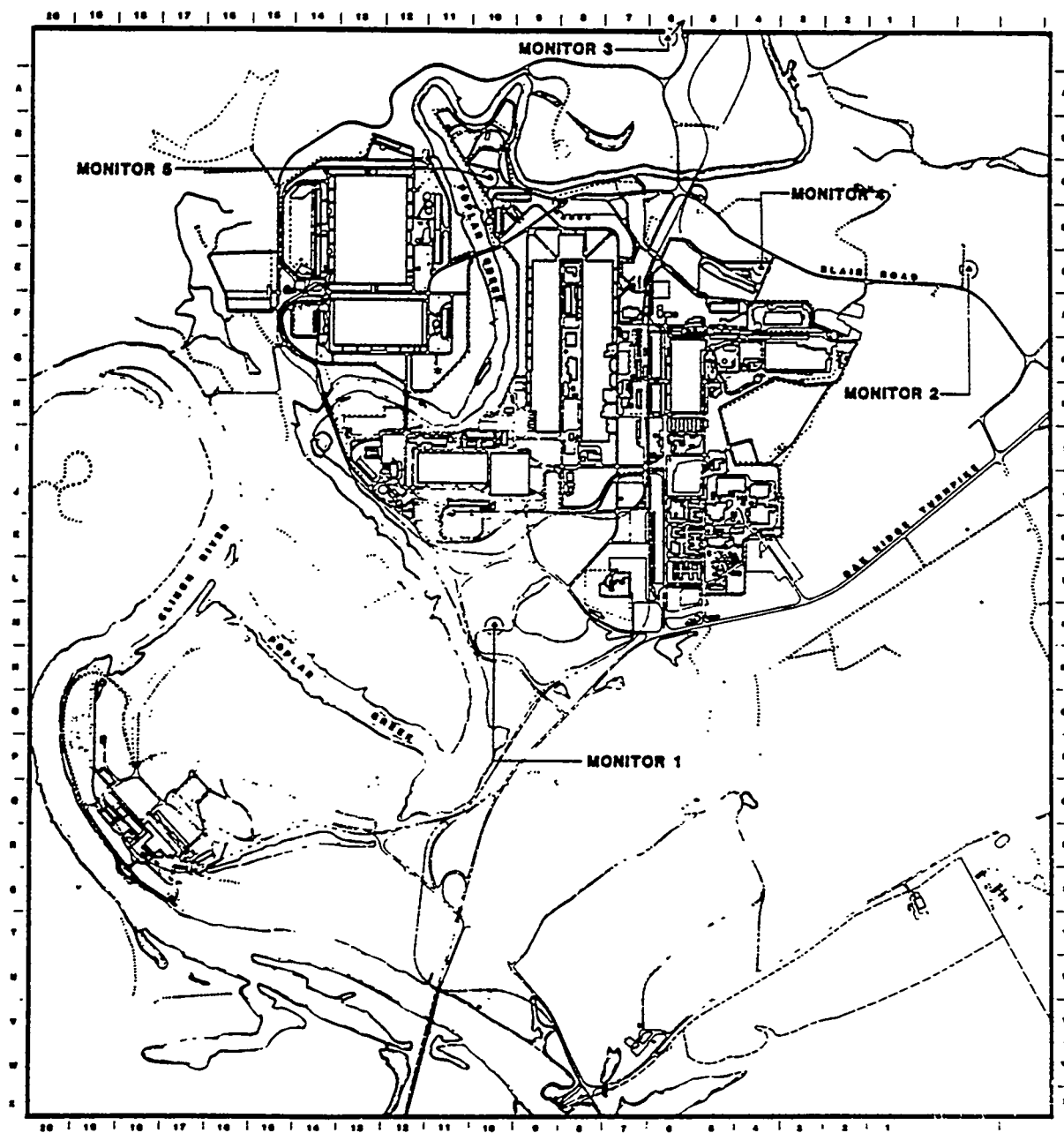


Fig. 4.8. Oak Ridge Gaseous Diffusion Plant Air Sampling Locations

compliance with the Tennessee Department of Health and Environmental (TDHE) standards within the calendar year 1985, with the exception of one point which was above the TDHE secondary standard of 150 g/m<sup>3</sup>. The maximum concentration of gaseous fluorides of a 7-day averaging period for all fluoride samples was 0.18 g/m<sup>3</sup> which is well below the state standard of 1.6 g/m<sup>3</sup>. The maximum concentration of gaseous fluorides over a 30 day averaging period for all of the fluoride monitoring system was 0.08 g/m<sup>3</sup> which is also well below the state standard of 1.2 g/m<sup>3</sup>. The maximum lead concentration of 0.74 g/m<sup>3</sup> is less than one half of the state standard of 1.5 g/m<sup>3</sup> per quarter. The other metals analyzed do not have emission limits but are monitored for operating purposes.



## 5. IDENTIFICATION OF POTENTIAL PATHWAYS OF MIGRATION AND POTENTIAL RECEPTORS

### 5.1 POTENTIAL PATHWAYS OF MIGRATION

Releases from SWMUs could be through subsurface, surface water, or atmospheric pathways. Important factors in subsurface transport are precipitation, the leaching characteristics of the contaminants, the transport rates through soil and bedrock, the depth to aquifers, and the rate of transport through aquifers. Surface water transport is related to precipitation, runoff, overflows, and evapotranspiration. Atmospheric transport is not considered a predominant pathway in the units under review. It will be addressed as needed in the specific site documents.

#### 5.1.1 Subsurface Transport

Soils and groundwater are of primary interest in addressing subsurface transport. Soils are important because of their role in retaining contaminants and retarding the migration of contaminants to the groundwater. The clays and shales typical of the ORGDP site have low hydraulic conductivities and are chemically active due to the large variety of charged ions which can exchange and immobilize metals. These clays and shales also tend to filter particulates. Rock and soil units are generally not homogeneous, and there are a number of geologic features such as sand channels or fault zones that can create pipeline effects and provide a route of rapid transmission of water through and

away from the ORGDP site.

The potential for prolonged soil contamination depends on the soil type at each specific site. The diversity of soil types at ORGDP ranges from soils with very little exchange or immobilization capacity to those with fairly high capacities. Those soils with high capacities would be expected to remain contaminated for extended periods of time.

The primary determinant of the rate of migration of pollutants in the ground is the movement of groundwater. Typically the local groundwater recharge area from precipitation moves along relatively short flow paths from the areas of infiltration to the Clinch River or Poplar Creek. The relatively moderate relief of the area provides insufficient hydraulic head for deep groundwater circulation. The bedrock lithology, geologic history, and regional structure do not appear to provide deep permeable zones for groundwater flow beyond the local system.

The surficial aquifer can be considered as a single, though complex, unit. The unconsolidated material is relatively homogeneous, and the groundwater flow is generally predictable. Contours of the water table and groundwater flow lines, inferred from water levels in 40 wells, are shown in Figure 4.4. Groundwater gradients are generally low throughout the plant site due to the subdued nature of the topography. This fact, coupled with the relatively low permeability of the surficial material ( $10^{-5}$  to  $10^{-4}$  cm/sec), results in extremely slow velocities of groundwater flow, on the order of  $10^{-4}$  ft/day.

### 5.1.2 Surface Water Transport

The ORGDP site is located near the confluence of the Clinch River and Poplar Creek. These waters eventually reach the Tennessee-Ohio-Mississippi water system. The hydrology of the Clinch River-Poplar Creek system is highly complex due to the flow alternations induced by Melton Hill and Watts Bar dams. The flow in the vicinity of the ORGDP site can be downstream, upstream, or zero. Water withdrawals from the Clinch River are used for industrial cooling water and potable water.

### 5.1.3 Atmospheric Transport

Atmospheric transport will be covered as needed in the specific site documents.

## 5.2 POTENTIAL RECEPTORS

### 5.2.1 Human Populations

Human populations of interest are those located near the boundary of the Oak Ridge Reservation (potential groundwater contamination) and those located downgradient from the ORGDP site. There are 25 known groundwater wells within one mile of ORGDP as shown in Figure 5.1. Groundwater wells known to be located within one mile of the units include wells installed at the TVA Blair Road Station, the Blair Road Building at the intersection of Blair Road and Highway 58 (Oak Ridge Turnpike),

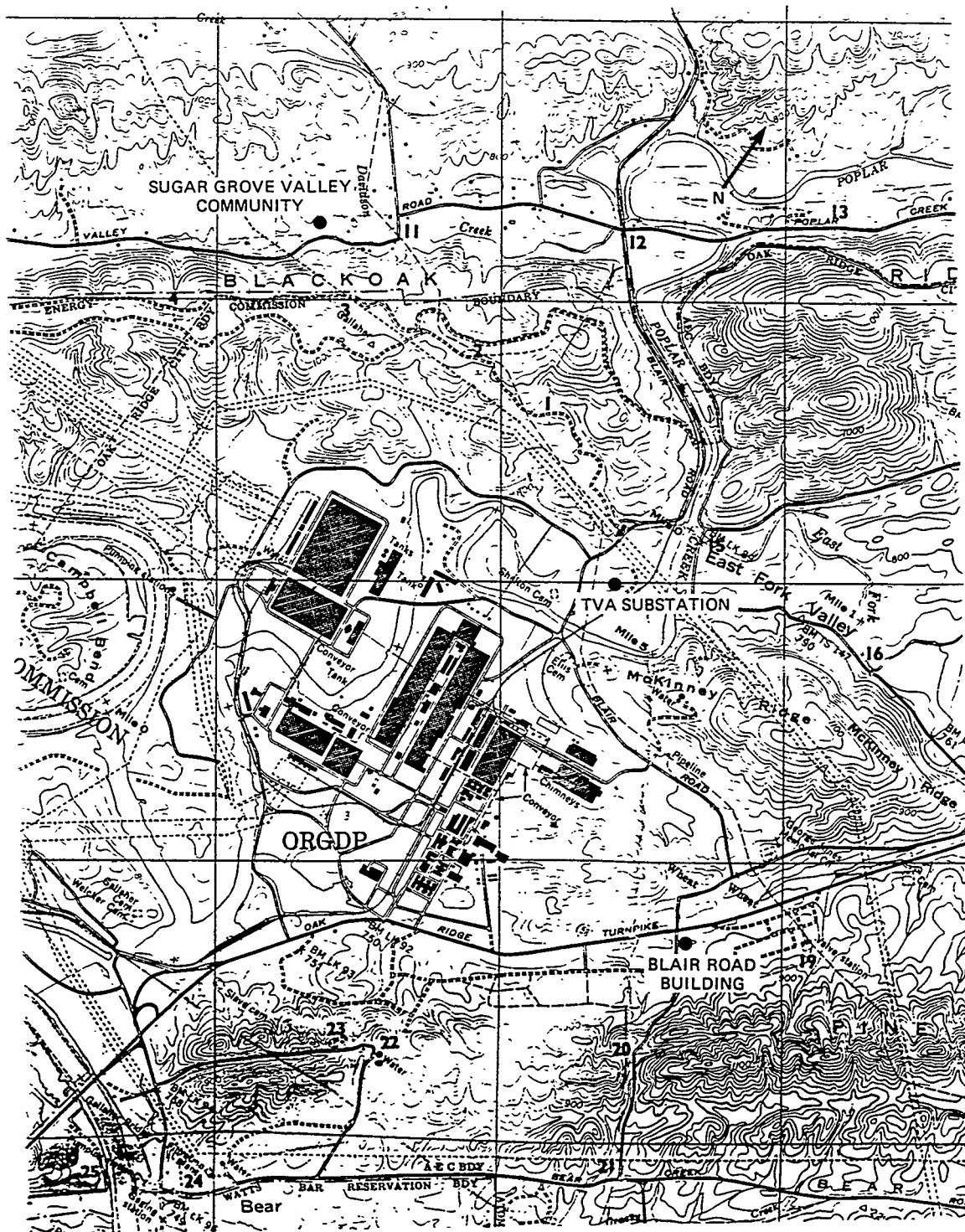


Fig. 5.1. Area Groundwater Wells Within One Mile of the ORGDP

and the residences located in the Sugar Grove Valley Community. Based on the geology/hydrology at ORGDP, it is unlikely that these wells could be affected by the disposal SWMU of interest at ORGDP.

There are 10 public water supply systems serving 91,500 people that withdraw surface water within a 32-km (20-mile) radius of the ORR, as listed in Table 5.1. Of these supply systems, only one is downstream of the ORGDP outfalls. The intake for Kingston is located at Tennessee River kilometer 914.2 (TRM 568.2), about 0.6 km (0.4 miles) above the confluence of the Clinch and Tennessee Rivers and 34.1 km (21.2 miles) below the ORGDP outfall. Kingston withdraws approximately 9% of its average daily supply from the Tennessee River. The city of Rockwood withdraws 1% of its average daily supply from Watts Bar Reservoir. Its intake is located 2 km (1.3 miles) from the mouth of King Creek embayment near TRK 890 (TRM 553).

Industrial water withdrawals from the Clinch-Tennessee system are listed in Table 5.2. Recreational use of the surface waters is heavy with swimming, fishing, and boating popular.

The geographic proximity of ORGDP to human populations are shown in Figures 5.2 and 5.3. Figure 5.2 shows the location of residents just offsite of the ORR, and Figure 5.3 shows communities within a 100-km (60 miles) radius of the ORR.

### 5.3 TERRESTRIAL FLORA AND FAUNA

The diverse vegetative communities in the area, primarily

Table 5.1. Public supply surface water withdrawals within 32 kilometers of the Oak Ridge Reservation

Public Supply System	Population Served (thousand)	Average Withdrawal Rate (m <sup>3</sup> /s)	Withdrawal Source and Location	Distance from ORR (km)
Clinton	6.2	0.03	CRK <sup>1</sup> 106.7	25.1
Harriman	10.0	0.10	ERK <sup>2</sup> 20.8	21.7
Kingston	5.0	0.014	TRK <sup>3</sup> 914.2	20.9
Lenoir City	6.6	0.04	TRK 967.5	16.6
Loudon	5.2	0.03	TRK 953.0	21.7
Anderson County Utility Board	8	0.03	CRK 89.3	14.3
Cumberland Utility District of Roane and Morgan Counties	4.3	0.008	LEREK <sup>4</sup> 3.5	14.0
First Utility District of Knox County	10.5	0.05	SCEK <sup>5</sup> 2.7	18.7
Hallsdale-Powell Utility District	28.7	0.07	BRCEK <sup>6</sup> 2.1	18.2
West Knox County Utility District	15.0	0.06	CRK 74.2	16.3

<sup>1</sup>CRK = Clinch River kilometer<sup>2</sup>ERK = Emory River kilometer<sup>3</sup>TRK = Tennessee River kilometer<sup>4</sup>LEREK = Little Emory River Embayment kilometer (Tennessee River)<sup>5</sup>SCEK = Sinking Creek Embayment kilometer<sup>6</sup>BRCEK = Bull Run Creek Embayment kilometer (Clinch River)

Table 5.2. Industrial water withdrawals from the Clinch-Tennessee River system

Industrial Water User	Average Withdrawal Rate (m <sup>3</sup> /s)	Withdrawal Source and Location	River Distance from Mouth of Poplar Creek (km)
Modine Manufacturing Co.	0.05	CRK 103.7	80.2
Tennessee Valley Authority Bull Run Steam Plant	25	CRK 77.2	52.7
U.S. Department of Energy ORNL, Y-12, Scarboro Facility, and City of Oak Ridge	0.96	CRK 66.8	42.3
ORGDP	0.13	CRK 23.3	1.2
ORGDP	0.54	CRK 18.5	6.0
Tennessee Valley Authority Kingston Steam Plant	61.3	ERK 2.9	20.6
Watts Bar hydro plant, lock, and steam plant	0.02	TRK 851.5	85.5

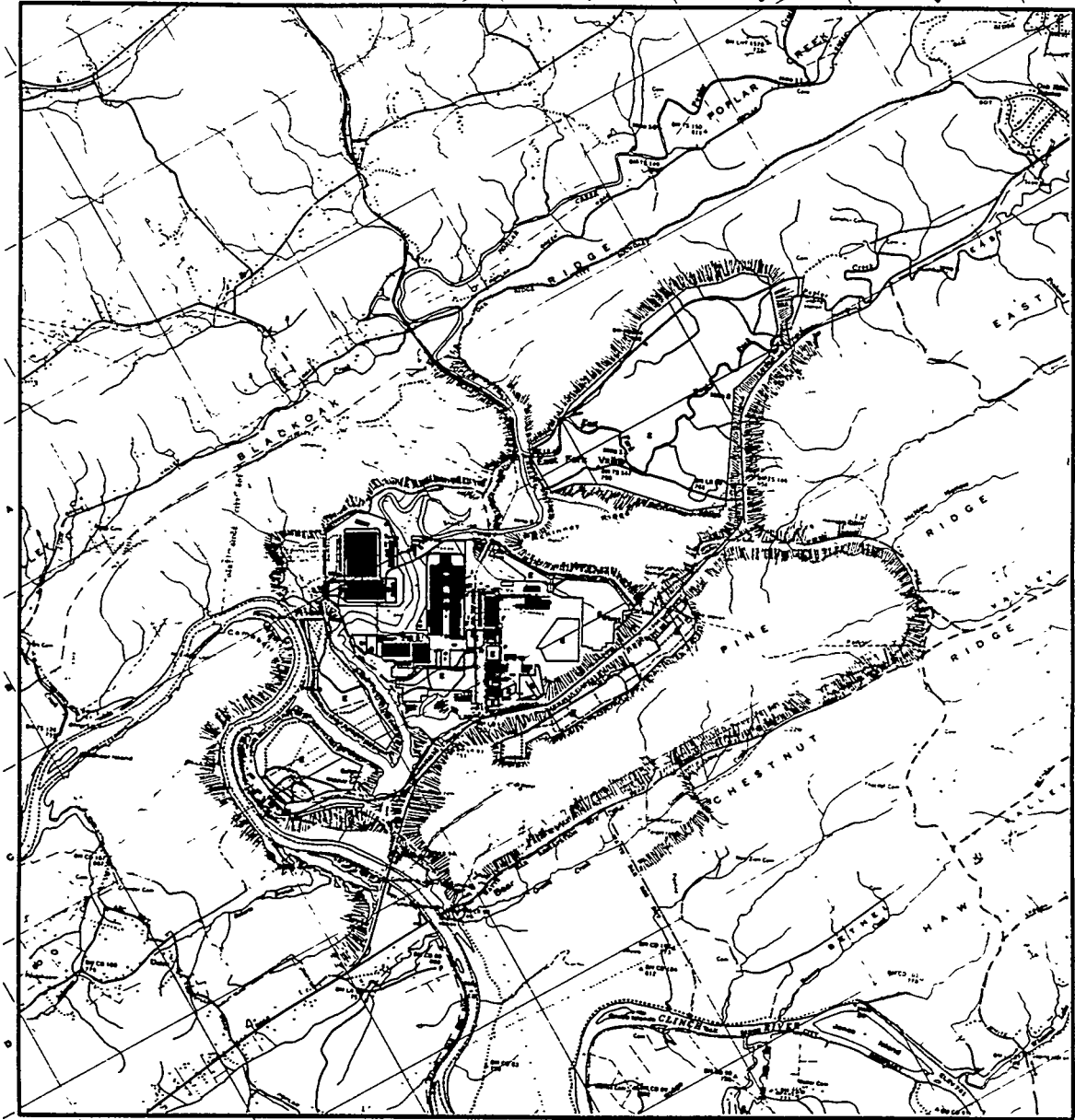


Fig. 5.2. ORGDP Site and Vicinity



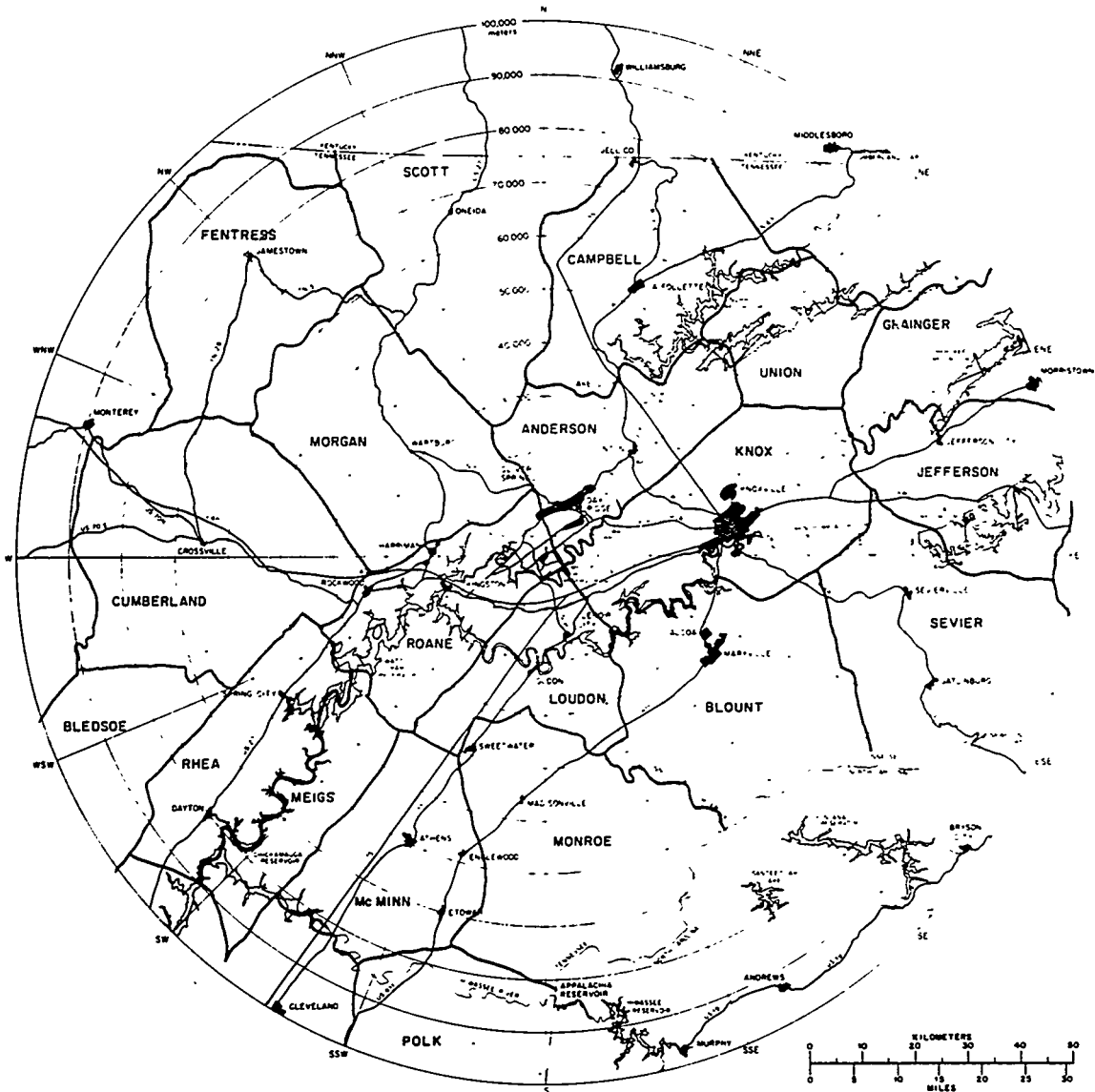


Fig. 5.3. Communities with a population greater than 1500 within a 100-km radius (60 miles) of the Oak Ridge Reservation

woodland, provide a varied habitat for many wildlife species. Many communities found on the site are typical of East Tennessee, an area rich in flora and fauna. There are 16 plant species and 18 wildlife species in the area which are considered rare, threatened, or endangered. The problems with these species are related to alteration or loss of habitat and have not been linked to contamination.

Five species of terrestrial fauna considered endangered by the U.S. Department of the Interior have been observed on or around the Oak Ridge Reservation. To date, there has been no study conducted to determine if any of these endangered species actually reside within one mile of ORGDP. The only two federally endangered mammalian species likely to occur on the reservation are the Indiana myotis (Motis sodalis) and the gray myotis (Myotis grisescens). The Indiana bat inhabits caves and hollow trees and may occur on the area. Many of these bats have been reported from New Mammoth Cave in Campbell County, 88.5 km (44 miles) from Oak Ridge. Neither the Indiana or gray bat has been reported on the ORR.

Three Federally endangered birds have been reported on the reservation or in its general vicinity. The southern bald eagle (Haliaeetus l. leucocephalus) has been observed along the Clinch River. A nesting site has been located on Watts Bar Reservoir. The ORR appears to be within the established range of this species. The peregrine falcon (Falco peregrinus [subspecies not indicated]) has been reported from Knox County and is considered

a fall, winter, and spring visitor to the Tennessee Valley. It has not been reported on the ORR. The red-cockaded woodpecker (Picoides borealis) is known to occur in Cumberland County, about 56 km (35 miles) from ORGDP. This woodpecker requires mature pines infected with red-heart disease for nest cavity construction. No nests, however, have been reported on the Reservation.

The eastern cougar (Felis concolor) has been sighted on the ORR numerous times.

Thirteen species of terrestrial fauna known or expected to occur in the area of the ORR are classified as endangered or threatened by the state of Tennessee. The Tennessee cave salamander (Gyrinophilus palleucus), reported from Roane County, is considered threatened. The Bachman's (pinewoods) sparrow (Aimophila aestivalis) and the sharpshinned hawk (Accipiter striatus) have been observed on the reservation and are considered endangered.

One bird species considered endangered in Tennessee, the osprey (Pandion haliaetus), and four bird species considered threatened in Tennessee, the Cooper's hawk (Accipiter cooperi), the marsh hawk (Circus cyaneus), the Bewick's wren (Thyromanes bewickii), and the grasshopper sparrow (Ammodramus savannarum), are expected to occur on the Oak Ridge Reservation.

#### 5.4 GENERAL OBSERVATIONS

Given the characteristics of the ORGDP site, the most likely transport pathway is the Clinch River. Localized groundwater

contamination is possible, but the groundwater moves over relatively short flow paths to the Clinch River. None of the groundwater wells outside of the ORR is in the same hydrogeologic zone as the ORGDP disposal sites. There is no current indication that deep bed aquifers are receiving flow from the ORGDP recharge zone.

## 6. STATISTICAL SAMPLING PLAN

### 6.1 SAMPLING PLAN STRATEGIES

Sampling plans will be used, as needed, to obtain missing or additional data to support the characterization of the contaminant source, its environmental setting, and the release. It is the goal of the sampling plan to efficiently provide data of the quality and quantity necessary to adequately address the purposes of the sampling, to satisfy the requirements of the RCRA Facility Investigation Guidance Volumes 1, 2, and 3, and to provide necessary information for selecting appropriate corrective measures.

Presented below are general principles which will be followed when developing a sampling plan for a particular site and purpose. The sampling plans will be explained in detail in that site's RFI plan.

### 6.2 SAMPLE QUALITY

Foremost in importance in the development of a sampling plan is the need to assure the quality of the sample. The samples must be taken in such a manner so as to be individually representative of their immediate setting and collectively representative of their overall setting, according to their intended use. The samples must meet the needs of the overall plan, be practical, simple, and safe to collect. The method of collection is medium and purpose dependent, for example, grab, composite, integrated, scoop, etc.

### 6.3 GENERAL STRATEGIES

Three methods of determining sample locations will be used: judgmental, random, and systematic. In most cases, a grid or series of grids will be imposed over the region of interest in order to describe the sampling locations.

#### 6.3.1 Judgmental Placement of Samples

Judgmental placement of samples will be employed when specific site information exists and can be used to improve sampling efficiency. Judgmental sampling will usually be used in conjunction with random and systematic sampling since it has a potential to bias the resultant data. The negative aspects of judgmental sampling will be further lessened by the use of phased sampling strategies.

### 6.3.2 Random Placement of Samples

In general, random placement of samples will be the primary method of sample location when the region and release extent are known and a contaminant average will provide adequate description of a site, as opposed to the more detailed information provided by contaminant contours. This would be the case, for example, if the release was known to be contained within a fixed area, which did not require corrective measures or required corrective measures for the entire site. Random sampling will be used to control the locations for subsampling, for example, in forming a composite sample within a particular grid location. Random sampling will also be used in such circumstances where systematic and judgmental sampling have high potential of cause biasing or in cases where systematic sampling is too complex to conduct. In general, random sampling only allows estimation of contaminant means, not contour development.

### 6.3.3 Systematic Placement of Samples

Systematic placement of sampling locations on a grid system will be used whenever site descriptions more detailed than contaminant averages are needed. These would include contaminant contours and the location of extreme conditions and pathways. Systematic sampling has a small potential to bias the results and will often be used in conjunction with judgmental and random sampling in order to minimize this risk.

#### 6.4 FEATURES OF SAMPLING

Depending on the purposes of sampling and the amount of available information, the techniques addressed in the following subsections can be used to obtain high quality data.

##### 6.4.1 Randomized Sampling Order

The order of taking the samples will be randomized as a precaution against possible systematic sample biasing, with two exceptions. In some circumstances, sampling must be performed in a specific order or the essence of the samples will be altered. For example, sampling is always done upstream from the previously drawn sample. Secondly, a randomized order will not be used if it would cause an undue burden, decrease the ability of the samplers to take samples of consistent quality, or increase the chances of compromising sample integrity and judgment says that there can be no biasing due to a systematic sampling order. If this can not be assured, a compromise sampling scheme will be developed.

##### 6.4.2 Phased Sampling and Analysis

Sampling and laboratory analysis will sometimes be conducted in phases, with the results of the previous phase used to determine the strategies, numbers, and locations for the next phase. This can be beneficial in cases where very little is known about the contaminants, region extent or depth, pathways, times of migration, etc.



#### 6.4.3 Subdivision of Regions

Dividing large or diverse types of regions into subregions for separate sampling and inference purposes can improve the quality and efficiency of the results. Zones further from the contaminant source could require fewer samples. Statistical homogeneity of variance and model fitting assumptions are more reasonable for similar and smaller regions. This approach can increase the total number of samples needed and will be applied cautiously, as needs prescribe.

#### 6.4.4 Composite and Integrated Samples

Sample composites will be used when an averaging effect is desired, particularly for initial sampling efforts. It is recognized that composite samples lose information and that volatile organics are especially prone to loss. Composition will always be viewed as a trade off between obtaining average results for fewer analyses and losing information. However, no compositing will be performed on samples analyzed for volatile organics. When part of a phased strategy, composite samples can be followed by additional analyses on samples which were originally split from those samples comprising the composites. In this way, lost information can be recovered if needed.

#### 6.4.5 Holding Samples

In some cases, it may be beneficial to obtain several phases of samples during one sampling period. This will be considered

when the marginal cost of taking additional samples is small compared to the cost of setting up and sample quality is not compromised by storage effects. The additional samples would be analyzed on an as needed basis in order to better address the issue of interest. Further, when forming a composite sample, intermediate samples may be split with half going into the composite and half saved for future analysis if needed. This could be of particular value on composites of depth or boring samples.

#### 6.4.6 Replication

Estimates of statistical repeatability will be determined from replicate samples from within the same grid location and from duplicate laboratory analyses on the same sample. These estimates of sample-to-sample differences and analytical error will be used to statistically evaluate the resultant data, set confidence bounds, and test for significance of parameters of interest, including means and terms of the contour models.

### 6.5 NUMBER OF SAMPLES

The number of samples to be taken and the number to be analyzed will be determined by several factors. These include the time frame for completion, acceptability of end-of-phase confidence statements, consideration of any environmental limits on the contaminants, estimates of actual levels present, consequences of erroneous conclusions, size and complexity of the

source and its setting, and sampling considerations such as safety and environmental disturbance factors. By sampling in phases, information will be available after the first phase to assist in sample size selection for other phases.

#### 6.6 SITE-SPECIFIC DETAILS

Explicit description of the sampling plans will be presented in the site-specific RFI plans. These will include the purposes for sampling, grid sizes, location and number of samples, regions and subregions, number and details of planned phases, samples which will be held for later analyses, locations of replicate samples, identification of samples to receive duplicate analyses, description of composites and consequences, depth of sampling, frequency of sampling, and plans for data analyses and presentation.

## 7. SAMPLING AND ANALYTICAL METHODOLOGY

### 7.1 SAMPLING METHODOLOGY

#### 7.1.1 General Methodology

The following section will detail methods to be used for sampling of sites identified as requiring RFI studies. Procedures will be outlined for both soil and water sampling. Soil sampling methods will be outlined for surface, near, and deep sampling. Methods for surface water and test well sampling will be outlined. Air sampling methods will not be covered in this document as they will be highly site specific and will not be required at most sites. Requisite air sampling methods will be described in the site specific documents for those sites which require air monitoring. The standard methods referenced in the following section are taken from the Characterization of Hazardous Waste Sites-A Methods Manual-Volume II, Available Sampling Methods, Second Edition. (EPA/600/4-84/076). Methods for deep soil sampling are taken from drilling techniques required for installation of monitoring wells. Deep soil methods are described in the Manual for Groundwater Sampling Procedures or in appropriate ASTM methods as referenced in TEST METHODS FOR EVALUATING SOLID WASTE (EPA SW-846), 2nd edition, Section 1.4.

The basic objective of a sampling campaign is to collect a sample which is representative of the site so as to aid in determining the presence and identity of contaminants and the extent to which they have become integrated into the surrounding

environment. Since the sampling of some sites may present unique problems to sampling which can not be covered comprehensively by the general procedures, some modification of methods may be required at certain sites. The list of criteria to be considered in choosing a sampling method or in modifying a standard method follows:

- Representativeness. The sample possesses the same qualities or properties as the material under consideration. The degree of resemblance of the sample to the material in question is determined by the desired qualities under investigation and analytical techniques used.
- Sample size. This should be chosen carefully in respect to physical properties of the entire object and the requirements and/or limitations of both sampling and analytical techniques.
- Number and/or frequency of subsampling. Decisions on these considerations are based on what types of statistical information are desired and the nature of the material collected.
- Maintenance of sample integrity. For the parameters to be analyzed, the sample must retain the properties of the original medium conditions (at the time of sampling) through collection, transport, and delivery to the analyst.

#### 7.1.2 Surface Soil Methodology

Table 7.1 contains the standard methods to be used for the sampling of surface or near surface soil samples, silts, and sediments.

#### 7.1.3 Subsurface Soil Methodology

Table 7.2 contains the methods to be used for the sampling of subsurface soil samples.

Table 7.1. Sampling methods for near surface  
soils, sludges, and sediments

<u>MATRIX</u>	<u>METHOD</u>	<u>METHOD REFERENCE</u>
Soil	Spade and Scoop	EPA 600/4-84-076 Method II-1
Soil	Auger and Thin-wall Tube Sampler	EPA 600/4-84-076 Method II-2
Soil	Split-Barrel Sampler	ASTM D 1586-84
Sludge	Hand Corer	EPA 600/4-84-076 Method II-4
Sludge	Gravity Corer	EPA 600/4-84-076 Method II-5

Table 7.2. Subsurface soil sampling methods

<u>MATRIX</u>	<u>METHOD</u>	<u>METHOD REFERENCE</u>
Soil	Split-Barrel Sampling	ASTM D 1586-84 <sup>1</sup>
Soil	Thin-Walled Tube Sampling	ASTM D 1587-83 <sup>1</sup>
Rock or Extremely Hard Soil	Diamond Core Drill	ASTM D 2113-83

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<sup>1</sup>The method provides information on removal of overlaying soil before sample is collected.

The drillings will be performed by private drilling contractors. The drillers will be required to have the equipment and specific experience necessary to implement the procedures.

Cuttings generated as a result of the drilling operations will be retained within close proximity to the borehole. A durable ground cover, such as Visquene or the equivalent, will be placed over the surface of the ground in the vicinity of the drilling to ensure that drill cuttings do not come into contact with the ground. The ground cover will be of sufficient size to allow for the storage of equipment, tools, bits, etc. In the event that contaminated water or soil is encountered during drilling, the wastes will be properly containerized and disposed of in accordance with ORGDP Environmental Management procedures.

All equipment, tools, and drill rig will be steam cleaned between each drilling to minimize the potential for spread of contamination.

After sampling of each coring is complete, bored holes will be filled with a grout column to prevent any further contamination of the groundwater. The grout should be a cement-bentonite mixture proportioned at 3 to 5 pounds bentonite powder for each 94 pound sack of cement. Approximately 6-1/2 gallons of potable water are necessary for this mixture. The bentonite assists in the suspension of the cement particles and reduces shrinkage. Increasing the water content increases the amount of grout shrinkage; careful measurements of the water are important. The grout should be tremied in, with the tremie pipe



initially set at the bottom and then gradually moved upward. Grouting should continue until the cured grout is up to the ground surface and forms a pad. Because grouting is accomplished in increments, it is not recommended that a cement with a quick setting time be used, as the cement may set up in the lines of the grout pump.

Drilling logs will provide data on borehole depth. If there is not a drilling log available, then the depth of the borehole must be sounded out to determine the length of the bore. The length of the bore is used to calculate the volume of the bore and the volume of the grout needed.

#### 7.1.4 Liquid Sampling Methodology

Table 7.3 contains the standard methods to be used for the sampling of liquids. Surface waters and ground waters will be covered. The groundwater methods are for sampling of water from the monitor wells and do not include methods for well construction.

### 7.2 ANALYTICAL METHODOLOGY

#### 7.2.1 General Methodology

The following sections detail the analytical methods to be used for analysis of samples taken. The analytical procedures outlined will be matrix specific and will reference a standard procedure. The standard methods specified in the following

Table 7.3. Liquid Sample Methods

<u>MATRIX</u>	<u>METHOD</u>	<u>METHOD NUMBER</u>
Surface	Dipper	EPA 600/4-84-076 Method III-1
Surface	Pond Sampler	EPA 600/4-84-076 Method III-2
Surface	Peristaltic Pump	EPA 600/4-84-076 Method III-3
Surface	Kemmerer Bottle	EPA 600/4-84-076 Method III-4
Well	Purge/Peristaltic Pump	EPA 600/4-84-076 Method III-7
Well	Purge/Gas Pressure Displacement System	EPA 600/4-84-076 Method III-8
Well	Bucket Bailer	EPA 600/4-84-076 Method III-9
Well	Peristaltic Pump	EPA 600/4-84-076 Method III-10
Well	Submersible Pump	EPA 600/4-84-076 Method III-11

sections are taken from either the Methods for Chemical Analysis of Water and Wastes (EPA-600/4-79-020) or Test Methods for Evaluating Solid Waste (SW-846). The expected detection limits for each analyte will be included.

#### 7.2.2 Inorganic Analytical Methodology

Tables 7.4 and 7.5 contain the standard methods to be used for the analysis and preparation of the inorganic constituents.

#### 7.2.3 Organic Analytical Methodology

Table 7.6 is a list of organic constituents of interest and their required detection limits. Table 7.7 is a list of analytical procedures to be utilized in the analysis for various classes of organics.

#### 7.2.4 Methodology for Radiological Analyses

At present, RCRA does not regulate radioactive waste; thus, only a limited number of EPA documents outlining standard radiological methods exist. In general, the existing EPA methods are designed for the analysis of ground water. Table 7.8 is a list of Radioactive Isotopes of concern and recommended methodology for their analysis. The EPA procedures referenced in this table are taken from the Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA-600/4-80-032). Suggested procedures for radioactive nuclides and matrices not covered by

Table 7.4. Analytical procedures and detection limits for regulated inorganics

<u>ANALYTE</u>	<u>SOIL ANALYSIS PROCEDURE</u>	<u>WATER ANALYSIS PROCEDURE</u>	<u>REQUIRED DETECTION LIMIT (mg/L) (6)</u>
Al	EPA-6010(3) EPA-202.1(1) EPA-202.2(2)	EPA-200.7(3)	0.2
Ag	EPA-7760(1) EPA-7761(2) EPA-6010	EPA-272.1(1) EPA-272.2(2) EPA-200.7	0.01
As	EPA-7060(1) EPA-7061(4)	EPA-206.2(2) EPA-206.3(4)	0.01
Ba	EPA-7080(1) EPA-7081(2) EPA-6010	EPA-208.1(1) EPA-208.2(2) EPA-200.7	0.2
Be	EPA-6010 EPA-210.1(1) EPA-210.2(2)	EPA-200.7	0.005
B	EPA-6010 EPA-212.3(7)	EPA-200.7	
Cyanide	See App. IA	EPA-335.2	0.010
Cd	EPA-7130(1) EPA-7131(2) EPA-6010	EPA-213.1(1) EPA-213.2(2) EPA-200.7	0.005
Ca	EPA-6010 EPA-215.1(1)	EPA-200.7	5
Cr(total)	EPA-7190(1) EPA-7191(2) EPA-6010	EPA-218.2(2) EPA-200.7	0.010
Cr(+6)	EPA-218.5(2)	EPA-218.4(1)	
Co	EPA-6010 EPA-219.1(1) EPA-219.2(2)	EPA-200.7	0.050
Cu	EPA-6010 EPA-220.1(1) EPA-220.2(2)	EPA-200.7	0.025

Table 7.4. Analytical procedures and detection limits for regulated inorganics (cont.)

<u>ANALYTE</u>	<u>SOIL ANALYSIS PROCEDURE</u>	<u>WATER ANALYSIS PROCEDURE</u>	<u>REQUIRED DETECTION LIMIT (mg/L) (6)</u>
F	Ion Selective Electrode	Ion Selective Electrode	-
Fe	EPA-6010 EPA-236.1(1) EPA-236.2(2)	EPA-200.7	0.1
Hg	EPA-7471(5) EPA-245.2(5)	EPA-245.1(5)	0.0002
K	EPA-6010 EPA-258.1(1)	EPA-200.7	5
Li	EPA-6010	EPA-200.7	-
Mg	EPA-6010 EPA-242.1(1)	EPA-200.7	5
Mn	EPA-6010 EPA-243.1(1) EPA-243.2(2)	EPA-200.7	0.015
Mo	EPA-6010 EPA-246.1(1) EPA-246.2(2)	EPA-200.7	
Na	EPA-6010	EPA-200.7	-
Nb	EPA-6010	EPA-200.7	-
Ni	EPA-7520(1) EPA-7521(2) EPA-6010	EPA-249.1(1) EPA-249.2(2) EPA-200.7	0.04
P	EPA-6010	EPA-200.7	-
Pb	EPA-7420(1) EPA-7421(2)	EPA-239.2(2)	0.005
Sb	EPA-7040(1) EPA-7041(2) EPA-6010	EPA-204.1(1) EPA-204.2(2) EPA-200.7	0.06

Table 7.4. Analytical procedures and detection limits for regulated inorganics (cont.)

<u>ANALYTE</u>	<u>SOIL ANALYSIS PROCEDURE</u>	<u>WATER ANALYSIS PROCEDURE</u>	<u>REQUIRED DETECTION LIMIT (mg/L) (6)</u>
Se	EPA-7740(1) EPA-7741(4)	EPA-270.2(2) EPA-270.3(4)	0.005
Si	EPA-6010	EPA-200.7	-
Sr	EPA-6010	EPA-200.7	-
Th	EPA-6010	EPA-200.7	-
Ti	EPA-6010	EPA-200.7	-
Tl	EPA-279.2(2)	EPA-279.2(2)	0.01
U	EPA-908.0 EPA-6010	EPA-908.0 EPA-908.1 EPA-200.7	
V	EPA-6010 EPA-286.2(2)	EPA-200.7	0.05
Zn	EPA-6010 EPA-289.1(1) EPA-289.2(2)	EPA-200.7	0.02
Zr	EPA-6010	EPA-200.7	-

1) Flame AAS

2) Furnace AAS

3) ICP

4) Hydride generation with Flame AAS

5) Cold vapor AAS

6) Required detection limits are those obtained in pure water. The detection limits for samples may be considerably higher depending on the sample matrix.

7) Colorimetric Method

Table 7.5. Sample preparation procedures

<u>METHOD</u>	<u>PREPARATION MATRIX</u>	<u>PROCEDURE</u>
ICP	Soil	EPA-3050
Flame AAS	Soil	EPA-3050
Furnace AAS	Soil	EPA-3050
ICP	Water	EPA-3010
Flame AAS	Water	EPA-3010
Furnace AAS	Water	EPA-3020

Table 7.6. Organic analyte list and required detection limits

<u>VOLATILES</u>	<u>CAS NUMBER</u>	<u>DETECTION LIMITS</u>	
		<u>Water</u> (mg/L)	<u>Soil/Sediment</u> (mg/Kg)
Chloromethane	74-87-3	0.01	0.01
Bromomethane	74-83-9	0.01	0.01
Vinyl Chloride	75-01-4	0.01	0.01
Chloroethane	75-00-3	0.01	0.01
Methylene Chloride	75-09-2	0.005	0.005
Acetone	67-64-1	0.01	0.01
Carbon Disulfide	75-15-0	0.005	0.005
1,1-Dichloroethene	75-35-4	0.005	0.005
1,1-Dichloroethane	75-35-3	0.005	0.005
trans-1,2-Dichloroethane	156-60-5	0.005	0.005
Chloroform	67-66-3	0.005	0.005
1,2-Dichloroethane	107-06-2	0.005	0.005
2-Butanone	78-93-3	0.01	0.01
1,1,1-Trichloroethane	71-55-6	0.005	0.005
Carbon Tetrachloride	56-23-5	0.005	0.005
Vinyl Acetate	108-05-4	0.01	0.01
Bromodichloromethane	75-27-4	0.005	0.005
1,1,2,2-Tetrachloroethane	79-34-5	0.005	0.005
1,2-Dichloropropane	78-87-5	0.005	0.005
trans-1,3-Dichloropropene	10061-02-6	0.005	0.005
Trichloroethene	79-01-6	0.005	0.005
Dibromochloromethane	124-48-1	0.005	0.005
1,1,2-Trichloroethane	79-00-5	0.005	0.005
Benzene	71-43-2	0.005	0.005
cis-1,3-Dichloropropene	10061-01-5	0.005	0.005
2-Chloroethyl Vinyl Ether	110-75-8	0.01	0.01
Bromoform	75-25-2	0.005	0.005
2-Hexanone	591-78-6	0.01	0.01
4-Methyl-2-pentanone	108-10-1	0.01	0.01
Tetrachloroethene	127-18-4	0.005	0.005
Toluene	108-88-3	0.005	0.005
Chlorobenzene	108-90-7	0.005	0.005
Ethyl Benzene	100-41-4	0.005	0.005
Styrene	100-42-5	0.005	0.005
Total Xylenes		0.005	0.005



Table 7.6. Organic analyte list and required detection limits (cont.)

<u>SEMI-VOLATILES</u>	<u>CAS NUMBER</u>	<u>DETECTION LIMITS</u>	
		<u>Water</u> (mg/L)	<u>Soil/Sediment</u> (mg/Kg)
Phenol	108-95-2	0.01	0.33
bis(2-Chloroethyl) ether	111-44-4	0.01	0.33
2-Chlorophenol	95-57-8	0.01	0.33
1,3-Dichlorobenzene	541-73-1	0.01	0.33
1,4-Dichlorobenzene	106-46-7	0.01	0.33
Benzyl Alcohol	100-51-6	0.01	0.33
1,2-Dichlorobenzene	95-50-1	0.01	0.33
2-Methylphenol	95-48-7	0.01	0.33
bis(2-Chloroisopropyl) ether	39638-32-9	0.01	0.33
4-Methylphenol	106-44-5	0.01	0.33
N-Nitroso-Dipropylamine	621-64-7	0.01	0.33
Hexachloroethane	67-72-1	0.01	0.33
Nitrobenzene	98-95-3	0.01	0.33
Isophorone	78-59-1	0.01	0.33
2-Nitrophenol	88-75-5	0.01	0.33
2,4-Dimethylphenol	105-67-9	0.01	0.33
Benzoic Acid	65-85-0	0.05	1.6
bis(2-Chloroethoxy) methane	111-91-1	0.01	0.33
2,4-Dichlorophenol	120-83-2	0.01	0.33
1,2,4-Trichlorobenzene	120-82-1	0.01	0.33
Naphtalene	91-20-3	0.01	0.33
4-Chloroaniline	106-47-8	0.01	0.33
Hexachlorobutadiene	87-68-3	0.01	0.33
4-Chloro-3-methylphenol	59-50-7	0.01	0.33
2-Methylnaphtlene	91-57-6	0.01	0.33
Hexachlorocyclopentadiene	77-47-4	0.01	0.33
2,4,6-Trichlorophenol	88-06-2	0.01	0.33
2,4,5-Trichlorophenol	95-95-4	0.05	1.6
2-Chloronaphthalene	91-58-7	0.01	0.33
2-Nitroaniline	88-74-4	0.05	1.6
Dimethyl Phthlate	131-11-3	0.01	0.33
Acenaphthylene	208-96-8	0.01	0.33
3-Nitroaniline	99-09-2	0.05	1.6

Table 7.6. Organic analyte list and required detection limits (cont.)

<u>SEMI-VOLATILES</u>	<u>CAS NUMBER</u>	<u>DETECTION LIMITS</u>	
		<u>Water</u> <u>(mg/L)</u>	<u>Soil/Sediment</u> <u>(mg/Kg)</u>
Acenaphthene	83-32-9	0.01	0.33
2,4-Dinitrophenol	51-28-5	0.05	1.6
4-Nitrophenol	100-02-7	0.05	1.6
Dibenzofuran	132-64-9	0.01	0.33
2,4-Dinitrotoluene	121-14-2	0.01	0.33
2,6-Dinitrotoluene	606-20-2	0.01	0.33
Diethylphthalate	84-66-2	0.01	0.33
4-Chlorophenyl Phenyl ether	7005-72-3	0.01	0.33
Fluorene	86-73-7	0.01	0.33
4-Nitroaniline	100-01-6	0.05	1.6
4,6-Dinitro-2-methyphenol	534-52-1	0.05	1.6
N-nitrosodiphenylamine	86-30-6	0.01	0.33
4-Bromophenyl Phenyl ether	101-55-3	0.01	0.33
Hexachlorobenzene	118-74-1	0.01	0.33
Pentachlorophenol	87-86-5	0.05	1.6
Phenanthrene	85-01-8	0.01	0.33
Anthracene	120-12-7	0.01	0.33
Di-n-butylphthalate	84-74-2	0.01	0.33
Fluoranthene	206-44-0	0.01	0.33
Pyrene	129-00-0	0.01	0.33
Butyl Benzyl Phthalate	85-68-7	0.01	0.33
3,3-Dichlorobenzidine	91-94-1	0.02	0.66
Benzo(a)anthracene	56-55-3	0.01	0.33
bis(2-ethylhexyl)phthalate	117-81-7	0.01	0.33
Chrysene	218-01-9	0.01	0.33
Di-n-octyl Phthalate	117-84-0	0.01	0.33
Benzo(b)fluoranthene	205-99-2	0.01	0.33
Benzo(k)fluoranthene	207-08-9	0.01	0.33
Benzo(a)pyrene	50-32-8	0.01	0.33
Indeno(1,2,3-cd)pyrene	193-39-5	0.01	0.33
Dibenzo(a,h)anthracene	53-70-3	0.01	0.33
Benzo(g,h,i)perylene	191-24-2	0.01	0.33
alpha-BHC	319-84-6	0.00005	0.008
beta-BHC	319-85-7	0.00005	0.008
delta-BHC	319-86-8	0.00005	0.008
gamma-BHC (Lindane)	58-89-9	0.00005	0.008
heptachlor	76-44-8	0.00005	0.008

Table 7.6. Organic analyte list and required detection limits (cont.)

<u>SEMI-VOLATILES</u>	<u>CAS NUMBER</u>	<u>DETECTION LIMITS</u>	
		<u>Water</u> <u>(mg/L)</u>	<u>Soil/Sediment</u> <u>(mg/Kg)</u>
Aldrin	309-00-2	0.00005	0.008
Heptachlor Epoxide	1024-57-3	0.00005	0.008
Endosulfan I	959-98-8	0.00005	0.008
Dieldrin	60-57-1	0.0001	0.016
4,4'-DDE	72-55-9	0.0001	0.016
Endrin	72-20-8	0.0001	0.016
Endosulfan II	33213-65-9	0.0001	0.016
4,4'-DDD	72-54-8	0.0001	0.016
Endosulfan Sulfate	1031-07-8	0.0001	0.016
4,4'-DDT	50-29-3	0.0001	0.016
Endrin Ketone	53494-70-5	0.0001	0.016
Methoxychlor	72-43-5	0.0005	0.08
Chlordane	57-74-9	0.0005	0.08
Toxaphene	8001-35-2	0.001	0.16
AROCHLOR-1016	12674-11-2	0.0005	0.08
AROCHLOR-1221	11104-28-2	0.0005	0.08
AROCHLOR-1232	11141-16-5	0.0005	0.08
AROCHLOR-1242	53469-21-9	0.0005	0.08
AROCHLOR-1248	12672-29-6	0.0005	0.08
AROCHLOR-1254	11097-69-1	0.001	0.16
AROCHLOR-1260	11096-82-5	0.001	0.16

Table 7.7. Analytical procedures for organic analytes

<u>COMPOUND CLASS</u>	<u>WATER PROCEDURE(S)</u>	<u>SOIL/SEDIMENT PROCEDURE(S)</u>
Volatiles	EPA-8240 EPA-624	EPA-8240
Semi-volatiles	EPA-8250 EPA-8270 EPA-625	EPA-8250 EPA-8270
Pesticides/PCB	EPA-8080 EPA-608	EPA-8080

Table 7.8. Analytical procedures for radionuclide analysis

<u>Analyte</u>	<u>Water Analysis Procedure</u>	<u>Soil Analysis Procedure</u>
Gross alpha and beta	EPA-900.0	EPA-900.0 <sup>1</sup>
Radioactive Cs	EPA-901.0	EC-134 <sup>1,2</sup>
Gamma Emitting Radionuclides	EPA-901.1 EC-134 <sup>2</sup>	EC-134 <sup>1,2</sup>
Radioactive Sr	EPA-905.0 EC-184 <sup>2</sup>	EC-350 <sup>2</sup>
Actinide Elements	EPA-907.0 1635 <sup>2,3</sup>	1635 <sup>1,2</sup>
Radioactive Tc	EC-186 <sup>2</sup>	EC-355 <sup>2</sup>
Uranium	EPA-908.0 EPA-908.1 EPA-200.7 <sup>4</sup>	EPA-908.0 <sup>1</sup> EPA-6010 <sup>4</sup>

- 
- 1) Analyze according to prescribed method after completion of dissolution as described in Appendix A
  - 2) Prescribed procedure is contained in Appendix A
  - 3) Modified procedure-skip dissolution off filter step
  - 4) Final analysis by Inductively Coupled Plasma (ICP)

EPA methodology are contained as Appendix A. These methods have been used successfully by the ORGDP Analytical Chemistry Department's Radiochemistry Group.

### 7.3 QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

#### 7.3.1 Blanks

For each group of samples processed, procedural blanks should be carried throughout the entire sample preparation and analytical process. These blanks will be useful in determining if samples are being contaminated.

#### 7.3.2 Duplicate Samples

Duplicate samples should be processed on a routine basis and will be used to determine precision. The sample load will dictate the frequency, but 10% is recommended.

#### 7.3.3 Reference Samples

Spiked samples or standard reference materials should be employed to determine accuracy. A spiked sample should be included with each group of samples processed and whenever a new sample matrix is being analyzed.

#### 7.3.4 Calibration

The concentration of all calibration standards should be verified against a quality control check sample obtained from

an outside source. Calibration factors and calibration working curves must be verified at least once during each working day by the measurement of one or more calibration standards. If the response for the parameter measured varies from the predicted response for that parameter by more than 10%, the measurement should be repeated using a fresh calibration standard. Alternately, a new calibration curve or calibration factor must be prepared.

An ongoing log of pertinent calibration information, including recalibration dates, out of calibration dates, standards preparation dates, and primary standard sources should be maintained and be available for inspection.

#### 7.4 SAMPLE HANDLING AND PROCESSING

Procedural methods employed to assure that the samples eventually received by the analytical laboratory are unadulterated and retain their integrity are summarized below.

##### 7.4.1 Sampling Preservation and Handling

Once a sample has been collected, steps must be taken to preserve the chemical and physical integrity of the sample during transport and storage prior to analysis. The type of sample preservation required will vary according to the sample type and the parameter to be measured.

Preservation and storage requirements are described in the individual analytical methods referred to in Section 7.2.

Since these requirements vary with the analytical method to be employed, it may be necessary to prepare more than one container of the same waste if more than one type of analysis is to be conducted. The chemical makeup of the samples can alter the effectiveness of the preservation; therefore, all sample analyses should be performed as soon as possible after sampling.

#### 7.4.2 Chain of Custody

In order for the final analytical results to be meaningful, it is necessary to ensure a samples integrity from the point of collection to the final reporting of the results. An essential part of maintaining sample integrity is the ability to trace the possession and handling of the sample from inception through final disposition. The historical documentation which is maintained for each sample solely for the purpose of allowing sample possession to be traced is referred to as Chain of Custody.

Minimum requirements for the Chain of Custody, including sample seals, field log books, sample labels, and chain-of-custody records are outlined in Test Methods for Evaluating Solid Waste (SW-846), Section 1.3.

#### 7.5 IMPLEMENTATION

The Analytical Chemistry Department of the ORGDP Process Support Division will have the responsibility of coordinating sampling of sites, sample handling, processing, and analysis. The Analytical Chemistry Department is a full service facility



providing sampling, analysis, instrumentation, development, and consulting services supporting a wide variety of programs. A department staff of 30 chemists and engineers, 58 laboratory analysts and support personnel, and 4 instrument mechanics is available to meet the needs of most any project. Modern analytical instrumentation is available to meet the analytical protocols of EPA, NIOSH, ASTM, and other regulatory and standards organizations.

A major portion of the present work effort of the Analytical Chemistry Department is devoted to environmental and waste management programs. Services that can be provided include sample collection and archiving, analyses for virtually all species of interest for NPDES, RCRA, and CERCLA monitoring, hazardous waste testing, preparation of data reports, computer data base development, on-line instrument development and services, and on-site consulting.

Sampling services are available for surface and well waters, soils, sediments, and stored nonradioactive wastes. Samples are collected according to the EPA protocol, and chain of custody is implemented. Stack flow profiling and sampling can also be provided.

The laboratory can analyze for all priority pollutants, all species on the EPA Hazardous Substances List, and many of the compounds and elements in the latest Appendix 9 list. Analytical methods are available for sample types such as water, sediments, soils, plant tissue, air, and solid waste forms. Methods for

analysis of pollutants in water using the test procedures in the Federal Register, 40 CFR Part 136, October 26, 1984, are in place.

Liquid and solid wastes can be tested by the EP toxicity method. All types of samples including raw, treated, and stabilized wastes can be tested. Equipment is available to prepare and test solid specimens in varying grout formulations. The protocol specified in SW-846 is followed. Facilities are available to test samples according to the Toxic Characteristic Leaching Procedure (TCLP).

Extensive quality assurance programs that meet the requirements of EPA, state of Tennessee, ASTM, and other standards and regulations are or can be implemented. Analytical Chemistry Department has the following certifications and qualifications:

- American Industrial Hygiene Association Certified
- State of Tennessee Certified for Drinking Water Analyses
- EPA Contract Laboratory Protocol Qualified

A full-time Quality Assurance Program Manager reports directly to the Laboratory Manager. Quality assurance data related to any group of samples can be directly accessed via the Laboratory Information System. Spike and surrogate standard results are printed with the sample report. The laboratory participates in all applicable national quality control programs and many Martin Marietta Energy Systems, Inc., programs. There are over 400 distinct quality control programs active in the laboratory, and specialized QC programs can be developed readily.

## 8. DATA MANAGEMENT PROCEDURES

Each site specific RFI will be provided with a topographic map of the facility area citing the following features: elevation contours, facility layout, and site boundaries. Data presentations for each location, as appropriate, will be in tabular or graphical form per the categories given in Table 8.1.

Each data record will provide, at a minimum, the following information:

- Unique sample code
- Sampling location and sample type
- Sampling date
- Laboratory analysis identification number
- Property or component measured
- Result of analysis
- Detection limits
- Reporting units

Any sampling logs will provide, at a minimum, the following information:

- Sample type
- Sampling location
- Sampling method
- Date and time of sampling
- Temperature
- Weather

Table 8.1. Some uses of tables and graphics in a RFI

Tabular Displays

1. Display site information and measurements
  - Water table elevations
  - Subsurface stratigraphy
  - Sampling location coordinates
  - Precipitation and temperature data
  - Lists of site fauna and flora species
2. Display analytical data
  - List of contaminants of concern and other monitoring parameters with associated analytical measurements
  - Display sorted results (e.g. by medium, sampling date, soil type)
  - Compare study and background area data
  - Report input data, boundary conditions, and output values from mathematical modeling

Graphical Displays

1. Display site features
  - Layout and topography (equivalent to required RCRA Part B permit application map)
  - Sampling locations and sampling grids
  - Boundaries of sampling area
  - Subsurface stratigraphy (profile, transect or fence diagram)
  - Wind rose
  - Potentiometric contour map
  - Population plot and/or local residential map
  - Features affecting intermedia transport
2. Illustrate the extent of contamination
  - Geographical (areal) extent of contamination
  - Vertical distribution of contaminant(s)
  - Contamination values, averages, or maxima at sampling locations
3. Demonstrate patterns and trends in the data
  - Plot change in concentration with distance from the source
  - Change in concentration with time
  - Display estimates of future contaminant transport derived from modeling

## 9. HEALTH AND SAFETY PROCEDURES

### 9.1 HEALTH AND SAFETY ORGANIZATIONS AT ORGDP

General health and safety procedures are well established and in place at ORGDP. These procedures are supported by the Plant and Support Protection (PS&P) Division and the Health, Safety and Environmental Affairs (HS&EA) Division. A Quality Assurance program is established which includes a strong focus on the health and safety of ORGDP employees and the general public. Martin Marietta Energy Systems policy places the responsibility for protecting the health and insuring the safety of employees and the public on the line organization. However, major roles are played by several divisions in providing resources and developing and coordinating programs and activities to support the line managers and supervisors. The Health, Safety and Environmental Affairs Division and the Plant Support and Protection Division have a more direct acting role while the Process Support Division and the Quality Assurance organizations are in position of support.

### 9.2 PLANT SUPPORT AND PROTECTION (PS&P) DIVISION

An organization chart defining Plant Support and Protection division functions is presented in Figure 9.1.

#### 9.2.1 Fire Protection Organization

The PS&P division maintains a Fire Protection Operations Department responsible for an extensive fire protection system which includes various types of fixed (e.g. wet and dry sprinkler

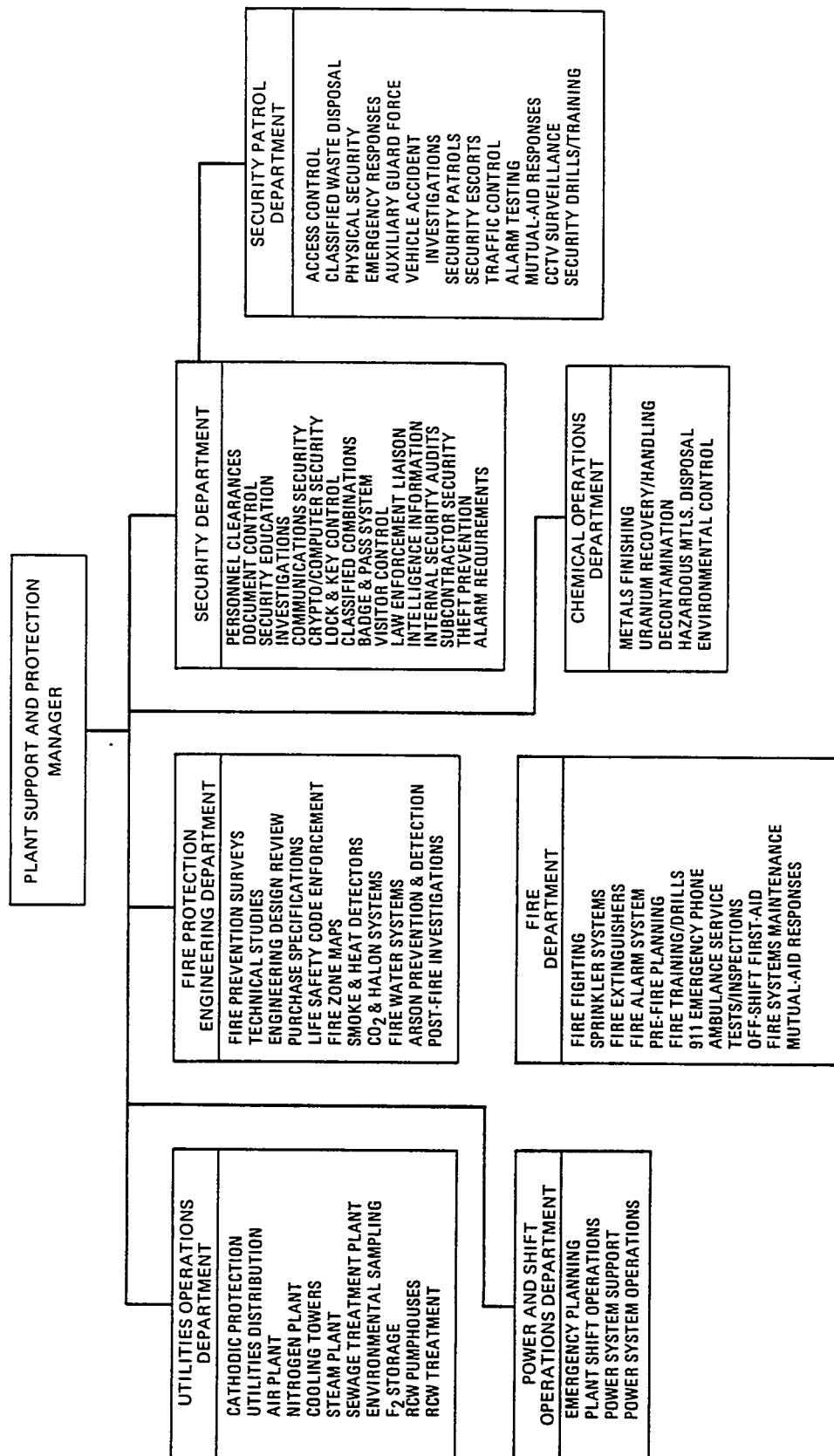


Fig. 9.1. Functional Organization Chart for the Plant Support and Protection Division, ORGDP

systems) and mobile equipment. The latest in fire-fighting equipment is utilized in a 24 hour fire department response capability including two pumpers, a 125' aerial platform truck and pumper combination, two state licensed ambulances and a fully equipped emergency response vehicle.

#### 9.2.2 Shift Superintendent Organization - Emergency Response

The PS&P division also provides a 24 hour emergency response coverage which is the responsibility of the Shift Superintendents, Power and Shift Operations Department. Direction of emergency efforts are necessary to assure that all emergency units act as a team in cases of serious emergencies. The Shift Superintendent on duty is the Plant Emergency Direction. He is assisted by a well trained plant emergency squad and is the overall coordinator in responding to any emergency such as fire, major equipment failure, hazardous material releases or spills, natural disasters, sabotage, etc. As would be expected, the Shift Fire Captain is responsible for directing the fire fighters. The scope of the Shift Superintendents responsibilities is summarized in Table 9.1.

#### 9.2.3 Security Organization

The Security Operations Department of the PS&P division assures the integrity of the plant security barriers and access portals, controls access to and egress from the plant, provides briefings on security as well as health and safety issues to

Table 9.1. Shift Superintendents operating manual  
plantwide emergency procedures

1200.0 . . . Occurrences Notification and Reporting . . . . .

CIVIL DEFENSE AND DISASTER PROCEDURES

1200.1 . . . Tornado Emergency Plan . . . . .  
 1200.2 . . . Mutual Aid . . . . .  
 1200.3 . . . Bomb Threat Emergency Plan . . . . .  
 1200.4 . . . Civil Disturbance. . . . .  
 1200.5 . . . Air Attack . . . . .  
 1200.6 . . . Disaster Plans, Natural or Man-Made. . . . .  
 1200.7 . . . Security Alert Plan. . . . .  
 1200.8 . . . Security and Safeguards Response . . . . .  
 1200.9 . . . Command Post Exercise Setup. . . . .

HAZARDOUS AND TOXIC MATERIALS RELEASE PROCEDURES

1200.20 . . . Uranium Hexafluoride Release . . . . .  
 1200.21 . . . Discharge or Release of Hazardous Materials to  
 the Environment . . . . .  
 1200.22 . . . Transportation of Y-12 Waste . . . . .  
 1200.23 . . . A Fast, Qualitative Determination of  $\text{UO}_2\text{F}_2$  in Air.

RADIATION EXCURSION PROCEDURES

1200.30 . . . Radiation Emergency. . . . .  
 1200.31 . . . Radiation Equipment (A Brief Operating Guide). . .

MISCELLANEOUS EMERGENCY PROCEDURES

1200.40 . . . Plant Evacuation and Accountability Plan . . . . .  
 1200.41 . . . Fire Department First Alarm and Phase Two  
 Emergency Alarm Response . . . . .  
 1200.42 . . . Emergency or Unusual Situations at the  
 Contaminated Scrap Yard. . . . .  
 1200.43 . . .  
 1200.44 . . . Contamination of the Sanitary Water Treatment  
 Facility Raw Water Intake. . . . .  
 1200.45 . . . Management of Abandoned Facilities . . . . .  
 1200.46 . . . Helicopter Overflight or Landing Authorization . .



visitors, controls uncleared personnel visits, with escorts, in the plant, conducts routine patrols of storage facilities in controlled areas, and provides traffic control during emergencies.

### 9.3 HEALTH, SAFETY AND ENVIRONMENTAL AFFAIRS DIVISION

An organizational chart defining the Health, Safety and Environmental Affairs (HS&EA) divisional functions is presented in Figure 9.2. The objectives of the HS&EA division include providing the resources and developing, coordinating, and monitoring policies, programs, and activities at ORGDP to ensure the health and safety of all employees and the public. These services are provided in accordance with Martin Marietta Energy Systems policies and in compliance with all applicable DOE, EPA, and state regulations. The following sections describe HS&EA departments that will assist in monitoring RFI activities.

#### 9.3.1 Environmental Management

The Environmental Management Department of the HS&EA division coordinates and monitors environmentally related activities at ORGDP. Areas of responsibility include air pollution control, water pollution control, solid waste management, remedial action, and project review and coordination.

#### 9.3.2 Medical Department

The function of the medical Department of the HS&EA division

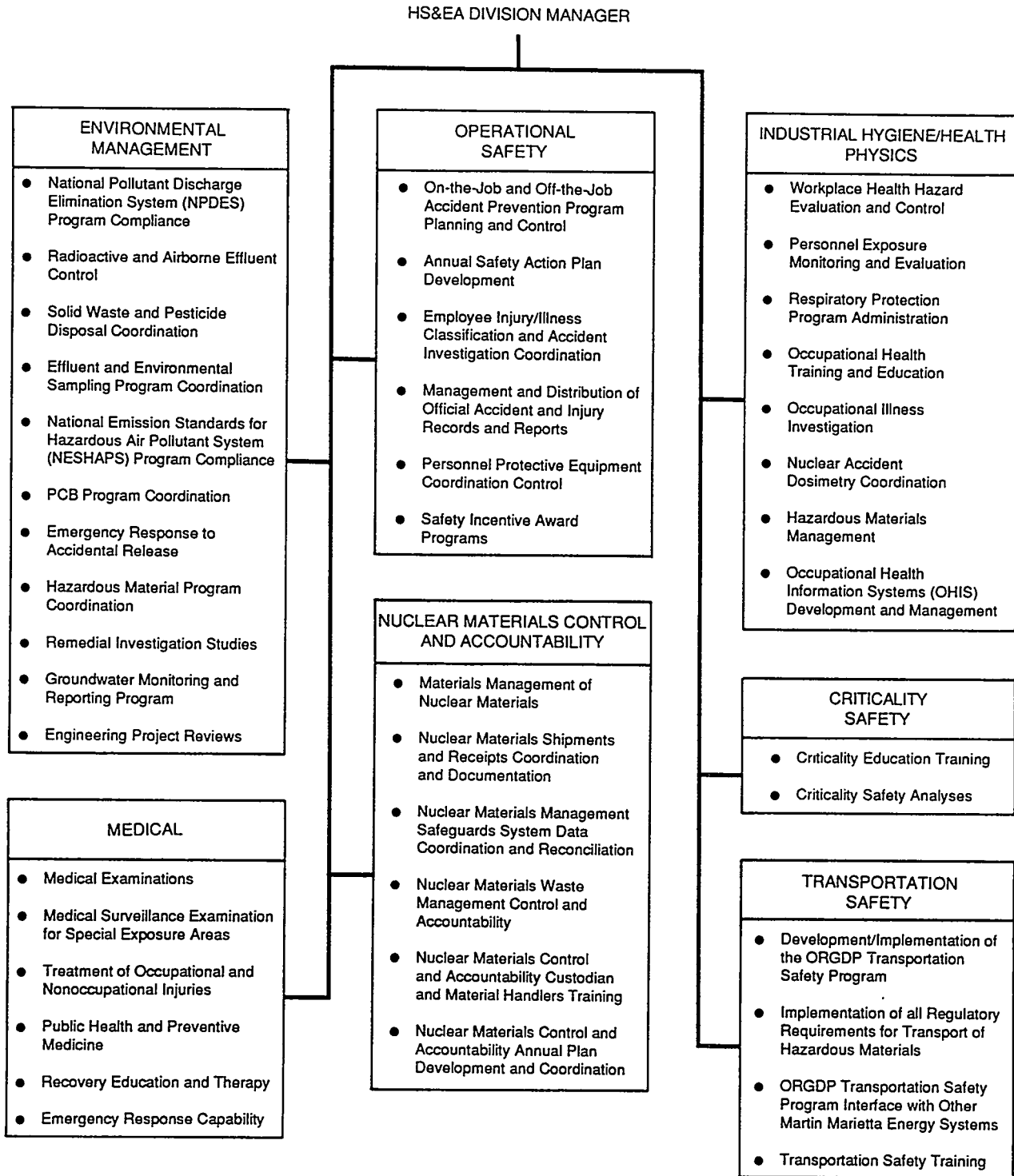


Fig. 9.2. Health, Safety, & Environmental Affairs Division Functional Organization Chart

is to provide occupational medical services that conform to good professional practice. The department is dedicated to achieving the following objectives:

- Provide a full range of medical diagnostic services to assist employees in achieving and maintaining optimal health.
- Provide routine and emergency medical care for occupational illnesses/injuries and limited emergency care for nonoccupational illnesses and injuries.
- Prepare and present health education/promotion programs, provide and encourage appropriate immunization programs, and instigate primary intervention programs.
- Maintain rehabilitation programs for employees to minimize nonproductive days away from work and to evaluate disability claims under Corporate pension plan or worker's compensation laws.

#### 9.3.3 Industrial Hygiene/Health Physics Department

The Industrial Hygiene/Health Physics Department of the HS&EA division assists management by providing a work environment conducive to the health and well being of employees and by establishing and maintaining the plant industrial hygiene and health physics programs such that radiation and chemical/physical exposure is limited to the lowest levels reasonably achievable.

The objectives of the Industrial Hygiene section are:

- Achieve and maintain the lowest practical level of employee exposure to physical and chemical stresses and ensure that exposures do not result in impaired health or well-being

- Recognize, interpret, and disseminate health regulations.
- Provide resources for planning, organizing, implementing, and appraising the effectiveness of health protection programs.
- Provide monitoring and analytical services for evaluation of employee exposure to chemical and physical stresses.

There are two Certified Industrial Hygienists and a Certified Industrial Hygienist Technologist on the staff of the Industrial Hygiene section.

The primary objective of the Health Physics section is:

- The limiting of ionizing radiation exposure of personnel to levels as low as reasonably achievable.

#### 9.3.4 Operational Safety

The Operational Safety Department of the HS&EA division is responsible for maintaining an effective accident prevention program that results in a safe and healthful work place for all employees. The Safety Department services are provided to comply with DOE, Occupational Safety and Health Act (OSHA), and state regulations in accordance with company policies and contract commitments to DOE. Safety department objectives are:

- Achieve and maintain the lowest possible level of accidents, injuries, and property damage at ORGDP.
- Provide the full range of safety engineering services to management for planning, organizing, implementing, and appraising effective accident/injury prevention programs.
- Recognize, interpret, and disseminate to all ORGDP organizations applicable federal, state, and local safety regulations and standards and monitor compliance.

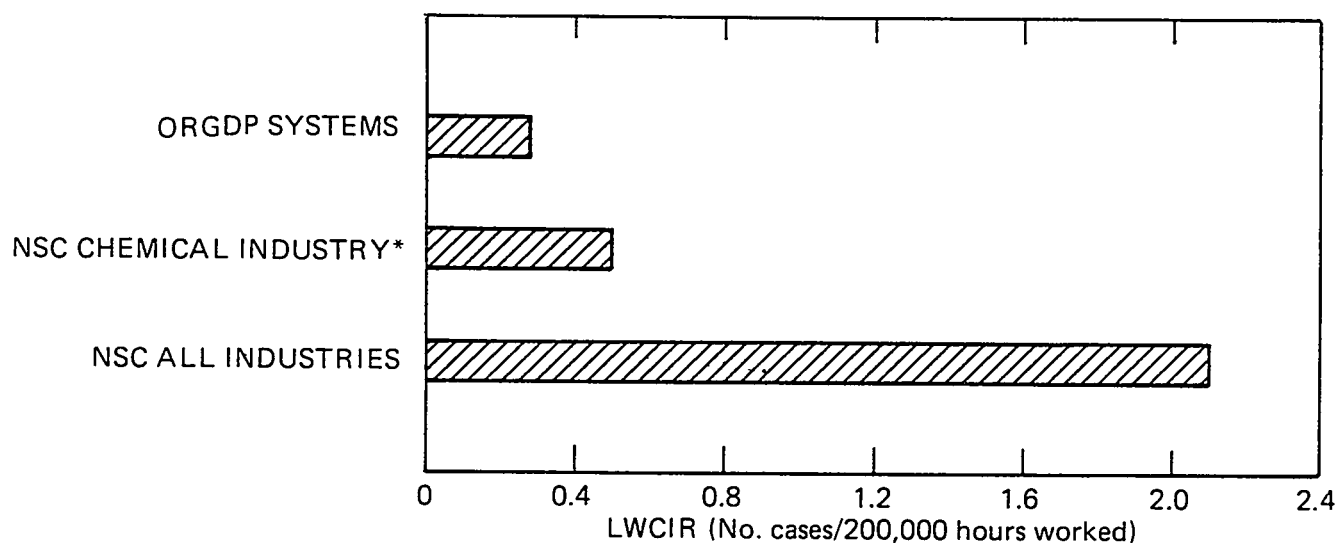
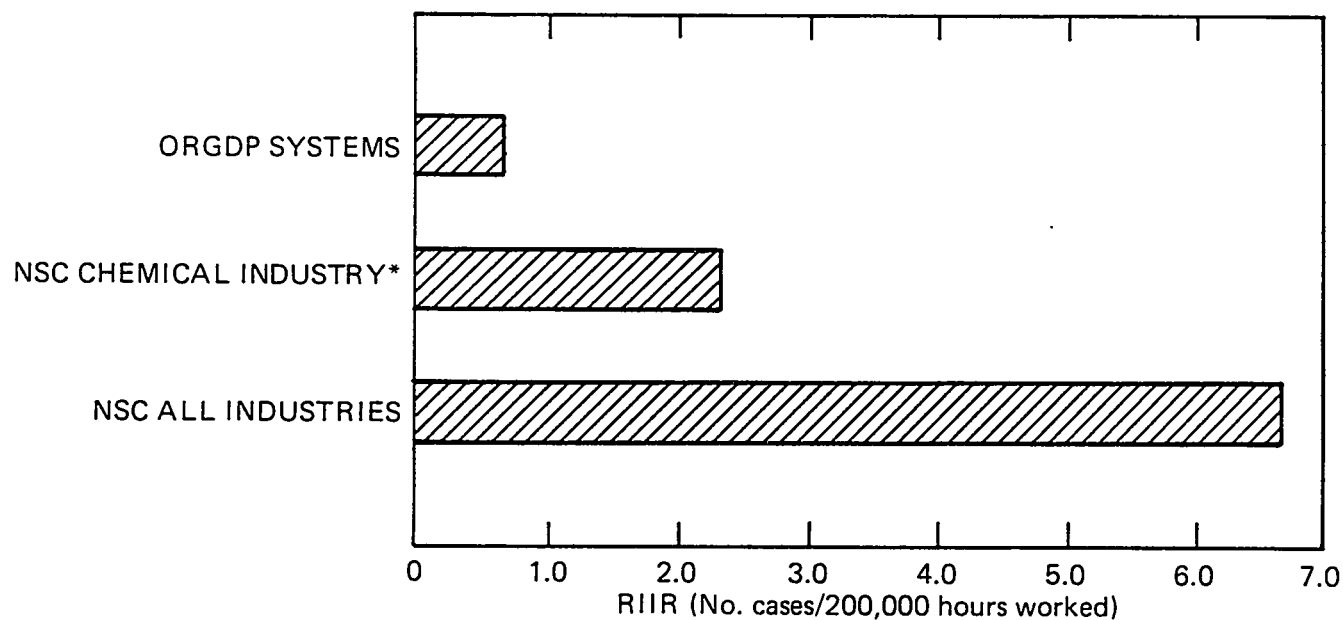
- Provide assertive/progressive direction in coordinating, promoting, and implementing ORGDP safety programs to ensure achievement of the highest DOE and Corporate performance ratings attainable.

The ORGDP utilizes a comprehensive Safety and Health Standards Manual which contains standards and procedures covering all aspects of protection provided employees and the public. This manual covers Safety Standards, Health Physics, Industrial Hygiene, Fire Protection, etc.

Performance indicators for employee injury rates at ORGDP are among the best in the nation. A comparison of ORGDP performance indication with all industry in the U.S. and the chemical industry in particular is shown in Figure 9.3. The scope of the ORGDP safety and health program is detailed in Safety Standard K-SS-1.1 and the standard for safety orientation, training, and control of service contractor personnel is detailed in Safety Standard K-SS-1.2.

#### 9.4 HEALTH AND SAFETY RESPONSIBILITY DURING RCRA FACILITY INVESTIGATIONS

The HS&EA division of ORGDP is responsible for adherence by the investigative team and any support personnel to the site Health and Safety Plan throughout the investigation. The site Health and Safety plan will conform to Occupational Safety and Health Administration (OSHA) standards 29 CFR 1910 as amended by adding the new section 1910.120 published in Federal Register/ Vol. 51 No. 244/ Friday, December 19, 1986/ Rules and

ORGDP LOST WORKDAY CASE INCIDENCE RATE (LWCIR)  
AVERAGE FOR PERIOD 1983-85ORGDP RECORDABLE INJURY/ILLNESS INCIDENCE RATE (RIIR)  
AVERAGE FOR PERIOD 1983-85

*\*BEST PERFORMING INDUSTRY IN NATIONAL SAFETY COUNCIL.*

Fig. 9.3. Comparison of Safety Performance Indicators for ORGDP with all U.S. Industry and the U.S. Chemical Industry

Regulations. The HS&EA Division will designate a Site Health and Safety Officer (SHSO) and an alternate to implement, monitor, and enforce the plan.

#### 9.4.1 Site Health and Safety Officer (SHSO) Responsibilities

The specific responsibilities of the SHSO are detailed below:

1. Identify key plant personnel (and alternates) who are responsible for specific safety related areas such as Medical, Plant Safety, Health Physics and Industrial Hygiene; in addition, establish liaison with Plant Security and Fire Protection and the Shift Superintendents organization to facilitate emergency response.
2. Keep the Medical Department updated on personnel work assignments and the potential safety and health hazards associated with the SWMU so that only qualified personnel are assigned to the site.
3. Establish and post at the SWMU site an emergency notification plan, telephone numbers, and appropriate radio communication frequencies.
4. Notify the Shift Superintendent organization at the beginning and conclusion of any activity at the SWMU site; state the expected schedule of work.
5. In the event of an unforeseen safety related condition or hazard becomes evident during investigation, cease operation, safeguard personnel, and re-establish safe working conditions.
6. Establish a health and safety training program that details the hazards of the site, the level of protection required, use of safety equipment, emergency procedures, decontamination procedures, and personal hygiene. The program should cover respirator fitting and the proper use and removal of protective clothing and safety equipment. All personnel assigned to the SWMU site in any capacity must be scheduled to attend a training program session, and attendance will be documented.

In the event Health and Safety responsibility is delegated to a subcontractor by Martin Marietta Energy Systems, Inc., these plans will be incorporated in the subcontract, and the SHSO of the HS&EA division will be responsible for coordinating and implementing the plan with the subcontractor.

#### 9.4.2 Determination of Work Area

The methodology that will be used in the establishment of the work zones for the SWMUs for which RFI reports will be written are given below:

##### 9.4.2.1 Zone 1: Exclusion Zone

The exclusion zone is the zone where contamination exists or could occur (See Figure 9.4). All personnel entering the exclusion zone will wear the prescribed level of protection. An entry and exit check point will be visually defined at the periphery of the exclusion zone to regulate the flow of personnel and equipment into and out of the zone.

Prohibitions in the exclusion zone will include the following:

- Beards and long sideburns;
- Eating, smoking, chewing;
- Personal articles, e.g., watches and rings;
- Working when ill; and
- Complete removal of respiratory protective equipment under Level C or higher protection.



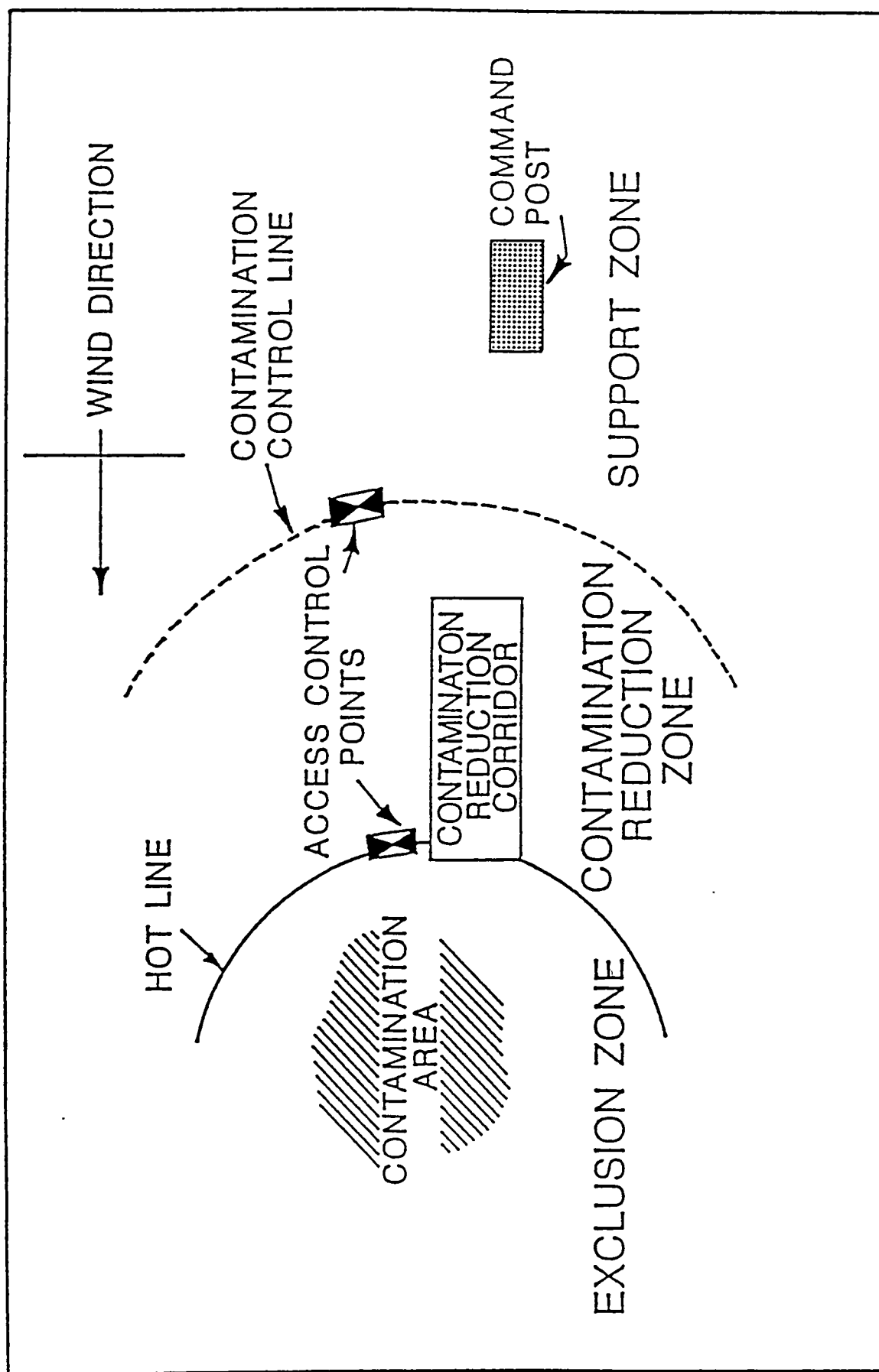


Fig. 9.4. Diagram of Site Work Zones

#### 9.4.2.2 Zone 2: Contamination Reduction Zone

As shown in Figure 9.4, a contamination reduction zone is established outside the exclusion zone. This zone provides a transition between a contaminated area and the clean zone. It serves as a buffer to further reduce the possibility of the clean zone becoming contaminated. It provides additional assurance that the physical transfer of contaminating substances on personnel, equipment, or in the air is limited through a combination of decontamination, distance between exclusion and support zones, air dilution, zone restrictions, and work functions. At the boundary between the exclusion and contamination reduction zones, decontamination stations will be established as described in the decontamination procedures.

#### 9.4.2.3 Zone 3: Support Zone

The support zone shown in Figure 9.4 is outside the zone of contamination. The support zone shall be marked and protected against contamination from the work site. The function of the area includes:

- An entry area for personnel, material, and equipment.
- An exit area for decontaminated personnel, materials, and equipment.
- A storage area for clean safety and work equipment.
- An area for rest breaks, the consumption of food and beverage, and all other activities.

#### 9.4.3 Levels of Protection for SWMUs at ORGDP

A format for designating the levels of personnel protection and monitoring to meet 29 CFR 1910.120 will be used in each RFI plan for the site specific SWMU (See Table 9.2).

The health and safety plans for the SWMUs at ORGDP are based upon requirements described in Volume I, Section 6 of the draft document, RCRA Facility Investigation Guidance, October 1986. Information gained from the hydrogeologic characterization of these sites during the fall and winter of 1985 and some limited supplementary data on specific sites are utilized. These locations were monitored for airborne ionizable pollutants, combustible gases and radioactivity during the time wells were being drilled. Field monitoring indicated workers were not exposed to concentrations of gases or radioactivity above the permissible exposure limits established by Martin Marietta Energy Systems, Inc. It currently appears that Levels C or D protection will be adequate for the exclusion zone of most of the sites.

#### 9.4.4 Safety Equipment Required for Designated Levels of Protection in the Exclusion Zone

Personnel protective equipment for the exclusion zone is based upon OSHA requirements. All respiratory protective equipment will be approved by the National Institute for Occupational Safety and Health (NIOSH)/Mine Safety and Health Administration (MSHA). Safety equipment required for the designated levels are as follows.

Table 9.2. Level of protection and  
monitoring parameters for SWMUs

<u>Level Designation</u>	<u>Monitoring Parameters</u>
A _____	Airborne Pollutants _____
B _____	Explosion Potential _____
C _____	Radiation _____
D _____	

## 1. Level A Protection

- a. Pressure-demand, full face piece self contained breathing apparatus (SCBA)
- b. Totally encapsulating chemical protective suit
- c. Gloves, outer, chemical-resistant
- d. Gloves, inner, chemical-resistant
- e. Boots, chemical-resistant, steel toe and shank
- f. Two-way radios (worn inside encapsulating suit)

## 2. Level B Protection

- a. Pressure-demand, full piece self contained breathing apparatus (SCBA)
- b. Hooded chemical-resistant clothing
- c. Gloves, outer, chemical-resistant
- d. Gloves, inner, chemical-resistant
- e. Boots, chemical-resistant, steel toe and shank
- f. Hard hat
- g. Two-way radios (worn under outside protective clothing)

## 3. Level C Protection

- a. Full face or half mask, air-purifying, cartridge or canister equipped respirator
- b. Hooded chemical-resistant clothing, long sleeves, one or two pieces
- c. Gloves, both inner and outer (chemical resistant)
- d. Steel toe boots/shoes (safety or chemical protective)
- e. Hard hat
- f. Options as required
  - 1) Coveralls (fire resistant)
  - 2) Inner chemical-resistant gloves
  - 3) Disposable outer boots (chemical-protective, heavy rubber vinyl disposables as appropriate)
- g. Two way radios (worn under outside protective clothing)

## 4. Level D Protection

- a. Coveralls
- b. Gloves
- c. Safety boots/shoes, chemical resistant steel toe and shank
- d. Goggles or safety glasses
- e. Hard hat

For discussion and further description of personnel protective equipment (PPE) and the types of hazards for which levels A,

B, C, and D protection are appropriate, see 29 CFR 1910.120 , Appendix B, pages 45763 and 45764, Federal Register/ Vol. 51 No. 244/ Friday, December 19, 1986/ Rules and Regulations.

#### 9.4.5 Decontamination Procedures

The purpose of decontamination is primarily to limit the spread of contaminated materials from the exclusion zone. This is accomplished through a step-by-step procedure whereby the protective clothing and equipment is either washed or disposed. The SHSO should exercise judgment in the establishment of the contamination reduction zone. Monitoring during work activities may indicate the need for additional stations under certain conditions. It is also possible that stations may be combined. Allowances must be made for the type or protective equipment being worn; e.g., non-disposable, steel toe outer boots need not be removed if properly decontaminated.

The decontamination procedures presented herein for Levels D and C are very similar; the only difference between the two levels is extra stations are present in Level C decontamination to account for respirator change or removal. Decontamination procedures for Levels A or B will be supplied in pertinent site specific RFI plans since only a limited number of sites will require protection levels greater than Level C.

Figure 9.5 serves as a visual aid in understanding the provisions for Level D decontamination described below.

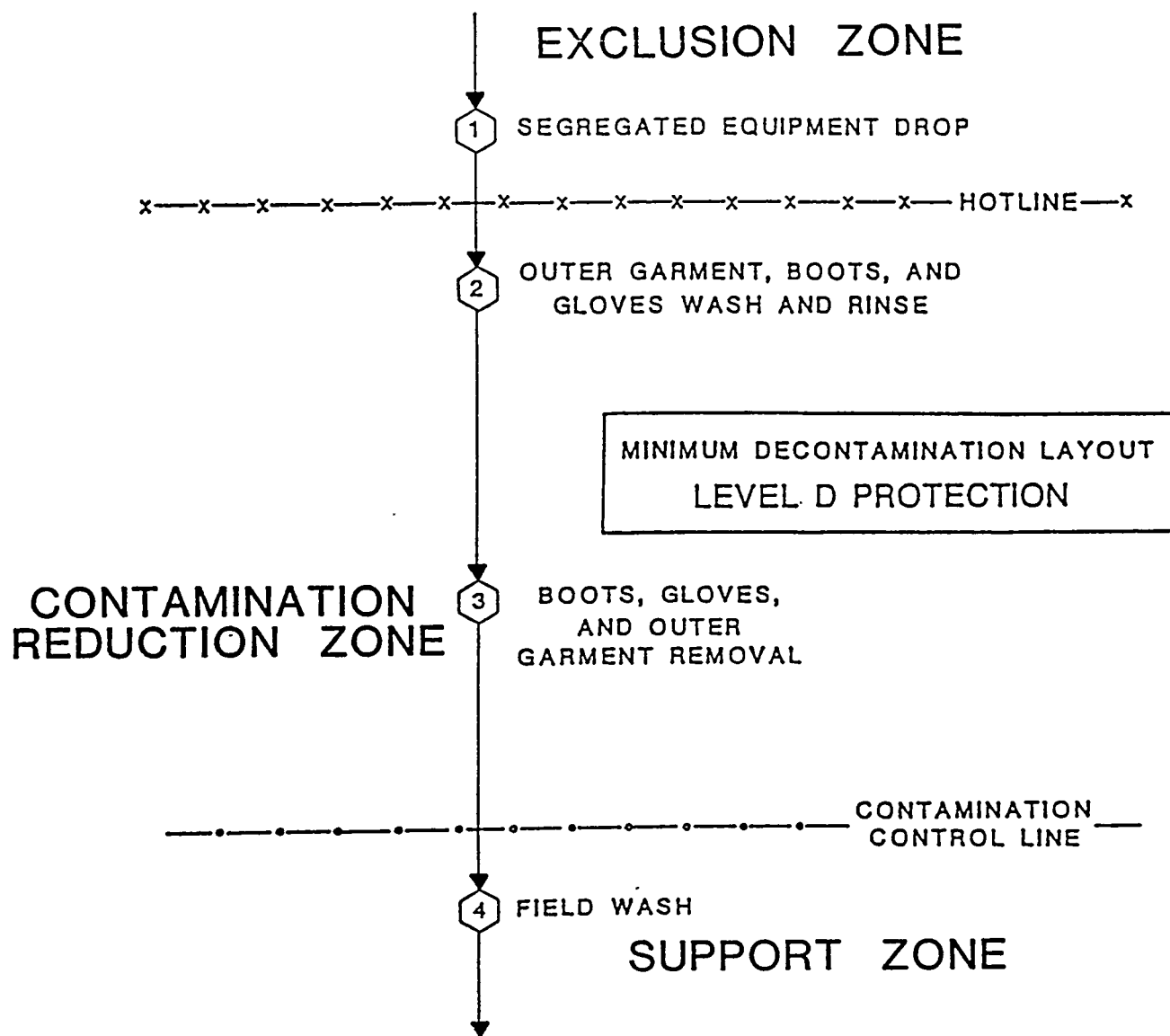


Fig. 9.5. Decontamination Layout — Level D Protection

Station 1: Segregated Equipment Drop

Deposit equipment used onsite (tools, sampling devices and containers, monitoring equipment, radios, clipboards, etc.) on a plastic drop cloth or in different container with plastic liners.

Equipment:        Various size containers  
                     Plastic liners

Station 2: Outer garment, boots, and gloves wash and rinse

Scrub outer boots and gloves with decontamination solution or detergent/water. Rinse gloves, boots, and garment with hand pump spray device.

Equipment:        2 containers (30-50 gallon)  
                     Hard pump spray device  
                     Water  
                     Detergent  
                     Scrub brushes

Station 3: Boot, gloves, and outer garment removal

Boots and outer gloves are removed and placed outside the decontamination zone. Inner gloves and Tyvek suit are deposited in separate containers lined with plastic.

Equipment:        Containers (30-50 gallon)  
                     Plastic liners

Station 4: Field wash

Thoroughly wash hands and face. Shower as soon as possible.

Equipment:        Water, wash basin/bucket, soap

Figure 9.6 serves as a visual aid in understanding the provisions for Level C decontamination described below:

Station 1: Segregated Equipment Drop

Deposit equipment used onsite (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths or in different containers with plastic liners. Each will be



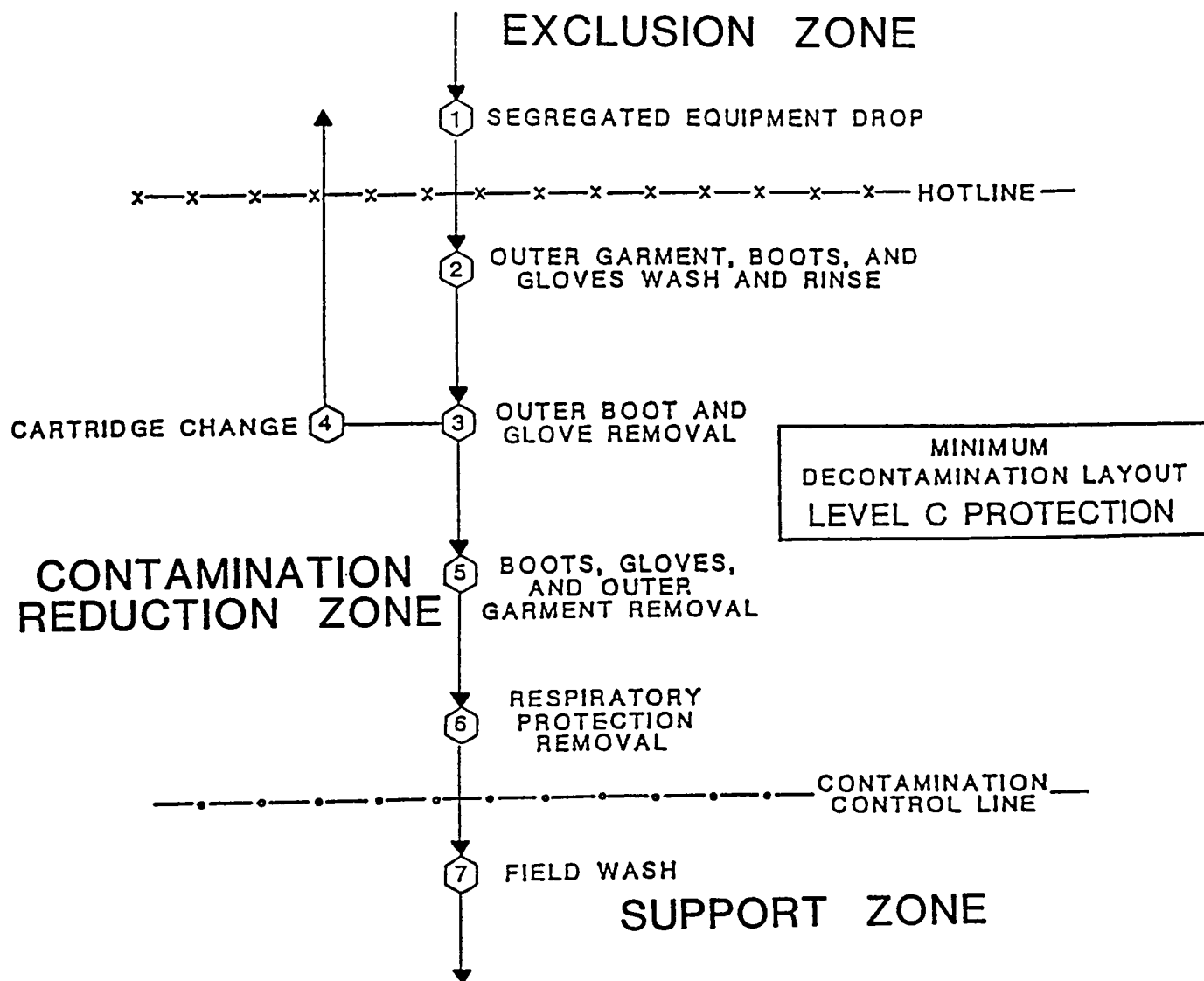


Fig. 9.6. Decontamination Layout — Level C Protection

contaminated to a different degree. Segregation at the drop reduces the probability of cross-contamination.

Equipment:        Various size containers  
                  Plastic liners  
                  Plastic drop cloths

Station 2: Outer Garment, boots and gloves wash and rinse

Scrub outer boots, gloves, and chemical resistant suit with decontamination solution or detergent/water. Rinse gloves, boots, and garment with clean water into plastic bucket.

Equipment:        2 containers (30-50 gallon)  
                  Water  
                  Detergent  
                  Scrub brushes, long-handle

Station 3: Outer boot and glove removal

Remove outer boots (if worn) and gloves with accompanying tape. Tape should be placed in a container with a plastic liner.

Equipment:        1 container (30-50 gallon)  
                  Plastic liner  
                  Bench or stool

Station 4: Canister/Cartridge Change

If a worker leaves the exclusion zone to change a canister/cartridge on his/her respirator, this is the last step in the decontamination procedure. Once the worker's canister/cartridge is exchanged, the outer gloves and boot covers are donned with joints taped. The worker may then return to the exclusion zone. All used canisters or cartridges will be disposed of at the end of the work day and fresh one installed prior to work start.

Equipment:        Respirator Canisters/Cartridges  
                  Tape  
                  Extra gloves  
                  Boot covers (if worn)

Station 5: Boots, gloves and outer garment removal

Removal of boots, gloves (inner), and outer garment. The outer chemically resistant garment and inner gloves should be deposited in a plastic lined container.

Equipment: Container (30-50 gallon)  
Bench or stool  
Plastic liners

Station 6: Respiratory Protection Removal

Remove the face piece respirator, deposit used cartridges in a plastic lined container, and wipe the face piece with clean water and paper towels.

Equipment: Container (30-50 gallon)  
Plastic liners  
Paper towels  
Detergent solution  
Rinse water

Station 7: Field Wash

Wash hands and face.

Equipment: Water  
Soap  
Wash basins/buckets

9.4.6 Site Monitoring

9.4.6.1 Airborne Pollutants

Employee exposure to airborne pollutants throughout the course of the investigation will be monitored through the use of air monitoring equipment. All air monitoring equipment will be calibrated prior to use each morning to provide comparable readings during the day and throughout the investigation. Organic pollutants will be monitored using the photoionization method to measure the concentration of organic vapors. Where airborne particulate monitoring is appropriate, a real-time aerosol monitor will be used. Combustible gases will be monitor-

ed; work activity will be stopped and the area evacuated if combustible gas levels exceed 10% of the lower explosive limit.

#### 9.4.6.2 Radiation Limits

The responsibility for limiting the exposure of the workers to non-hazardous levels of radiation resides in the SHSO. The SHSO will monitor for radiation in the air and adjacent to sample drillings and/or diggings with a radiation meter capable of measuring 0.1 mR/hr. Should the reading exceed 0.1 mR/hr, the SHSO will order work to be stopped and the crew removed from the exclusion zone. The SHSO will request the presence of a health physicist on site who will assess the potential hazard of the conditions and determine whether or not work should continue.

#### 9.4.6.3 Monitoring Frequency

Monitoring for organic vapors and radiation will be conducted within the exclusion zone at a minimum of every 10 feet sampled and every 30 minutes during drilling and sampling operations. All employees shall be assigned work functions within a single personnel protective level zone, when possible, to minimize the movement of personnel to and from the contaminated zone. Visitors and employees in a service capacity that remain in the support zone will not receive periodic exposure monitoring, nor will they be required to wear personnel protection.

#### 9.4.6.4 Monitoring Record Maintenance

The SHSO will be responsible for establishing and maintaining records of all monitoring required as described below:

- The date, time, boring number, depth of hole, meter reading and relevant comments shall be written in an instrument log book that shall be available for inspection at all times.
- A description of the analytical methods and equipment used.
- Type of respiratory protective devices worn.

#### 9.4.7 Respiratory Protection and Selection

The SHSO will require that respiratory protective equipment be used continuously when specified under criteria set forth in prior sections to reduce employee exposure to airborne substances.

For air purifying respirators, the SHSO will select the appropriate type of canister or cartridge-equipped respirator for all employees at the site. Prior to use of a respiratory protection device, SHSO will provide a respirator fitting to assure the proper use and fit of the device.

All subcontractors will provide respirators for their own employees from those approved by the National Institute for Occupational Safety and Health under provisions of 30 CFR Part II.

#### 9.4.8 Visitor Protection

All visitors to the SWMU sites shall be instructed to stay outside the work zone and remain within the support zone during the extent of their stay. Visitors shall be cautioned to avoid skin contact with contaminated or suspected contaminated surfaces. During visitation, hand-to-mouth transfers should be reduced with special precautions not to eat, drink, smoke, or chew gum or tobacco. The use of alcohol or medicine is prohibited.

Visitors requesting to observe work conducted in the exclusion zone must wear all appropriate personnel protective devices prior to entering the work zone. Should respiratory protective devices be necessary, visitors who wish to enter the work zone must produce evidence that they have had a complete physical examination and respiratory protection training, including respiratory fitting, within the past 12 months.

Visitor inspection of the work zone will be left to the discretion of the SHSO.

#### 9.4.9 On-Site Safety Equipment Requirements

The following safety equipment will be maintained onsite:

- Emergency eye wash
- First aid kit
- 17 lb halon fire extinguisher or equivalent
- Organic vapor analyzer
- Drinking cups
- Decontamination facilities
- Emergency horn
- Garbage bags
- Paper towels
- Garbage cans

- Brushes
- Spray container

The following instruments for monitoring organic vapor, airborne particulate, combustible gases, and radiation levels in the exclusion zone will be used at pertinent SWMU sites during work activities.

- Photoionization detector for organic vapors
- Real-time aerosol monitor for airborne particulate
- Combustible gas meter for explosive gases
- Geiger-Mueller (G-M) meter for radiation surveys
- High volume air sampler for monitoring airborne radiation

#### 9.5 ORGDP QUALITY ASSURANCE

The ORGDP has an institutionalized Quality Assurance (QA) program which focuses on the assurance of safe and successful operations. The program emphasizes prevention of potential problems, planned activities to reduce risks, and promotion performance improvement.

Responsibility for coordinating the QA activities within the plant and with the other gaseous diffusion plants has been assigned to the plant QA coordinator who reports to the plant manager. Division managers are responsible for implementing the QA program through their respective line organizations. Each division has a QA coordinator who is responsible for coordinating QA activities within the division, as directed by the division manager. An example of the present QA organization is shown in Figure 9.7.

The plant coordinator and the division coordinators make up

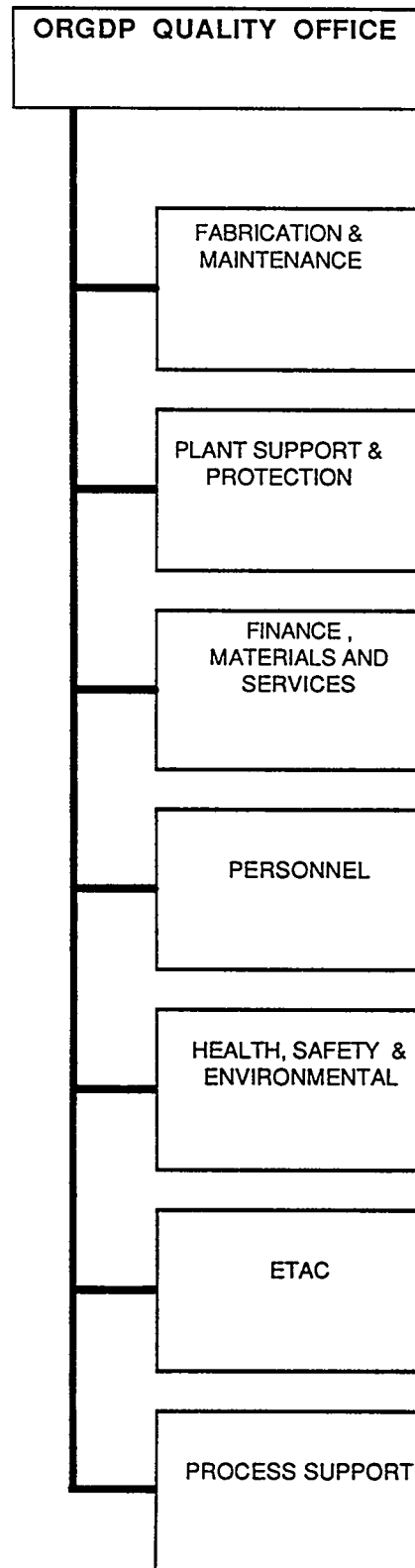


Fig. 9.7. ORGDP Quality Office Organization Chart



the plant QA committee, which functions under the direction of the plant manager and has the following basic responsibilities:

- Disseminate the doctrine of QA and quality improvement within the plant and encourage support of the QA program.
- Develop a comprehensive program of QA that will minimize significant quality problems in a cost-effective manner.
- Promote QA activity in conducting assessments; writing QA plans; developing procedures, reports, records, etc.; making certain that these items are accessible, adequate, and auditable.
- Help identify quality improvement opportunities.
- Assist in the investigation of quality problems and in the interpretation of QA program requirements.
- Provide guidance to line supervision relative to communicating QA policy, conducting internal audits, handling nonconformances, assigning responsibilities, effectively using statistical quality control (QC) concepts, and improving quality.
- Inform management of QA activities, quality problems, corrective actions, and the impact of quality problems on plant and multisite projects.
- Provide guidelines for collecting, analyzing, and reporting costs associated with major quality problems.

#### 9.6 GENERAL HEALTH AND SAFETY PROCEDURES FOR RFI

The ORGDP will be responsible for preparing and implementing the Health and Safety procedures to address the needs of the RFI. These procedures will be developed to protect the health and

safety of the investigating team, plant workers, and general public. The procedures will be compatible with the ORGDP Health and Safety Standards and will contain all pertinent safety information and instructions.

A general outline of the Health and Safety Plan (included in site specific RFI Plans) to be employed for the RCRA Facility Investigations of each SWMU at ORGDP is given in Table 9.3.

Table 9.3. ORGDP health and safety plan outline  
RCRA facility investigations of SWMUs

1. Introduction
2. Known Hazards and Risks
3. Level of Protection
4. Designation of Work Area Zones
5. Exposure Limits

## APPENDIX A

Preparation of Soil and Sludge Samples for  
Pu, Np, and Th via Ion Exchange

1. Transfer an exact weight (5 - 10 g) of the sample to a 500 ml tall form breaker. If the sample shows signs of containing organic matter, ash in a muffle furnace at 500 degrees C for several hours before continuing.
2. Slowly add 50 - 75 ml of 8 M  $\text{HNO}_3$  and allow sufficient time for any foaming to subside.
3. Add appropriate tracers at this time (Np-239, Pu-236, etc.).
4. Carefully introduce the magnetic stirring bar, place on the hot plate, and digest with stirring at 90 - 95 degrees C for one hour.
5. Remove from the hot plate and transfer the solution to two 50 ml plastic centrifuge tubes.
6. Centrifuge for 10 minutes at 1500 rpm.
7. Decant the supernatant liquid into a 250 ml beaker and retain it.
8. Rinse the residue from the centrifuge tube into the original 500 ml beaker with 50 - 75 ml  $\text{HNO}_3$ .
9. Return to the hot plate and digest with stirring at 90 - 95 degrees C for one hour with the addition of a few drops of 30% hydrogen peroxide intermittently for a total of 5 - 10 ml.
10. Repeat Steps 5 through 7.
11. Repeat Step 8 using 25 ml of 1M  $\text{HNO}_3$ .
12. Repeat Steps 9 and 10 and discard the residue.
13. Proceed to analyze the sample according to procedure number TP-1635.

Number 1635  
Analysis Th, U, Np, Pu  
Sample Air Filter  
Method Radiochemical  
Page 1 of 6

## TECHNICAL PROCEDURES

TITLE: Sequential Determination of U, Th, Np, and Pu on Air Filters

### METHOD

Thorium (Th), uranium (U), neptunium (Np), and plutonium (Pu) are dissolved from air filters with 4 M nitric acid ( $\text{HNO}_3$ ). An aliquot of the dissolved sample is evaporated and the residue is dissolved in 8 M nitric acid ( $\text{HNO}_3$ ). The Np and Pu in the sample are adjusted to the IV (+4) oxidation state by the addition of ferrous sulfamate and sodium nitrite. The sample is passed through an ion exchange column. Nonsorbed elements are eluted with 20 ml of 8 M  $\text{HNO}_3$ . Uranium, which is only weakly absorbed is eluted with an additional 125 ml of 8 M  $\text{HNO}_3$ . Thorium is eluted with 50 ml of 9 M hydrochloric acid (HCl). The Np and Pu are eluted together with 50 ml of 0.5 M HCl containing 2 ml of sulfurous acid. The eluted fractions containing the separated nuclides are electroplated on counting discs and counted on an alpha spectrometer.

### DETECTION LIMIT

The detection limit for each nuclide is 0.8 dpm per aliquot. With a 50 ml aliquot this is equivalent to 1.6 dpm/filter.

### PRECISION AND ACCURACY

The limit of error at the 95% confidence level is  $\pm 3$  dpm at a level of 10 dpm per filter for each nuclide. There are no significant biases.

### APPARATUS

1. Glass column, 9-mm ID, 15-cm long, fitted with a glass frit, stopcock, and filling reservoir.
2. Electroplating apparatus.
3. Alpha spectrometer: multichannel energy analyzer with a silicon surface-barrier detector.
4. Counting discs: stainless steel, 3.8 cm dia x 1-mm thick.
5. Primary and secondary calibration standards.

### REAGENTS

1. Dowex 1-X4 anion exchange resin, 100-200 mesh, analytical grade.
2. 8 M  $\text{HNO}_3$ : dilute 500 ml of conc.  $\text{HNO}_3$  to 1000 ml with distilled water

Number 1635  
Analysis Th, U, Np, Pu  
Sample Air Filter  
Method Radiochemical  
Page 2 of 6

## TECHNICAL PROCEDURES

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TITLE: Sequential Determination of U, Th, Np, and Pu on Air Filters

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3. 9 M HCl: dilute 375 ml of conc. HCl to 500 ml with distilled water.
4. 0.5 M HCl: dilute 83 ml of conc. HCl to 2,000 ml with distilled water.
5. Sulfurous acid ( $\text{H}_2\text{SO}_3$ ) 6% as  $\text{SO}_2$ .
6. 4 M  $\text{HNO}_3$ : dilute 125 ml of conc.  $\text{HNO}_3$  to 500 ml with distilled water.
7. 0.4 M Ferrous sulfamate: dilute 10 ml of 50% solution to 50 ml with distilled water.
8. 1 M sodium nitrite ( $\text{NaNO}_2$ ): dissolve 3.45g of  $\text{NaNO}_2$  in distilled water dilute to 50 ml.
9. Plating Solution: dissolve 26.75g of ammonium chloride ( $\text{NH}_4\text{Cl}$ ) and 0.63g of oxalic acid ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ) in distilled water and diluted to 500 ml. (pH should be between 2 and 2.5)
10. Isopropyl alcohol.

### PROCEDURE

#### Column Preparation

1. Condition the anion exchange resin by alternately washing it with 0.5 M HCl and water 3 times.
2. Fill the glass column with 0.5 M HCl. Make a slurry of the resin with 0.5 M HCl and pour it into the column. Allow the resin to settle with the stopcock open. Avoid air entrapment in the resin and never allow the liquid level to fall below the level of the resin.
3. Adjust the length of the resin column to 15 cm and top with a glass wool plug.
4. Pass 100 ml of 0.5 M HCl through the column and stop when the level is at the top of the column.

#### Sample Preparation

1. Fold the air filter and fit it into a porcelain crucible or other suitable ashing container.

TECHNICAL PROCEDURES

Number 1635  
Analysis Th, U, Np, Pu  
Sample Air Filter  
Method Radiochemical  
Page 3 of 6

---

TITLE: Sequential Determination of U, Th, Np, and Pu on Air Filters

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2. Wet the filter with ammonium hydroxide.
3. Place the crucible in a muffle furnace at 200°C until the filter is charred, then ash the filter at 525°C for 4 hours.
4. Remove the crucible from the furnace and allow to cool.
5. Dissolve the residue in 8 M  $\text{HNO}_3$  and a small amount of conc.  $\text{HCl}$ . Wash it into a 100 ml volumetric flask and dilute to the mark with 4 M  $\text{HNO}_3$ .

Nuclide Separation

1. Pipette 50 ml of the solution into a 150 ml beaker.
  2. Evaporate the solution, then dissolve the residue in 2 ml of 16 M  $\text{HNO}_3$  and evaporate again.
  3. Dissolve the residue in 3-5 ml of 8 M  $\text{HNO}_3$ .
  4. Ready the ion exchange column by passing 50 ml of 8M  $\text{HNO}_3$  through the column. (Use a flow rate of 2 ml/min for all column operations)
  5. Add 0.45 ml of 0.4 M ferrous sulfamate to the sample and place in a water bath at 55°C for 10 min. Allow to cool 20 min.
  6. Add 1.0 ml of 1.0 M  $\text{NaNO}_2$  and allow to react.
  7. Wait 15 min, then pass the sample through the prepared column.
  8. Rinse the beaker with 5 ml of 8 M  $\text{HNO}_3$  and pass the rinse through the column.
  9. Pass 20 ml of 8 M  $\text{HNO}_3$  through the column and discard the effluent.
  10. Pass 125 ml of 8 M  $\text{HNO}_3$  through the column and collect the effluent in a 150 ml beaker marked for uranium.
  11. Pass 50 ml of 9M  $\text{HCl}$  through the column and collect the effluent in a 150 ml beaker marked for thorium.
  12. Pass 50 ml of 0.5 M  $\text{HCl}$ , to which 2 ml of  $\text{H}_2\text{SO}_3$  has been added, through the column and collect the effluent in a 150 ml beaker marked for neptunium and plutonium.
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Number 1635  
Analysis Th, U, Np, Pu  
Sample Air Filter  
Method Radiochemical  
Page 4 of 6

## TECHNICAL PROCEDURES

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TITLE: Sequential Determination of U, Th, Np, and Pu on Air Filters

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13. Pass 50 ml of 0.5 M HCl through the column to wash the column for reuse and discard the effluent.

### Nuclide Plating<sup>3</sup>

1. Add 5 ml of conc HNO<sub>2</sub> to each of the beakers (steps 10, 11, and 12 above) and evaporate. Repeat 3 times.
2. Dissolve the residues in 5 ml of 12 M HCl and evaporate.
3. Dissolve the residues in 5 ml of plating solution and transfer to plating cells containing counting discs. Rinse the beakers with another 5 ml of plating solution and transfer the rinse to the plating cells.
4. Place the cells on the electroplating apparatus and plate for 20 min at 3 amp. Add distilled water as necessary to replace evaporation loss.
5. After 20 min, add 6 drops of NH<sub>4</sub>OH and plate an additional 1 minute before turning off the power.
6. Remove the cells and drain the electrolyte.
7. Rinse the cells with water and then with isopropyl alcohol.
8. Remove the discs from the cells and place them in a muffle furnace at 425°C for 5 min.

## COUNTING

### Instrument Calibration and Check

1. Determine the efficiency of the alpha spectrometer by calibrating with secondary standards which have been cross calibrated against an NBS certified primary standard. The secondary standards should be plated and counted with the same geometry as the samples.
  2. Count the secondary standards daily as a check of both energy and efficiency calibration and log the efficiency value. If the daily check of the calibration falls outside the 95% Confidence Limit for the established calibration, a recalibration should be made.
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## TECHNICAL PROCEDURES

Number 1635  
Analysis Th, U, Np, Pu  
Sample Air Filter  
Method Radiochemical  
Page 5 of 6

TITLE: Sequential Determination of U, Th, Np, and Pu on Air Filters

### Nuclide Counting

1. Place the sample counting discs in the alpha spectrometer and count for 4,000 sec.
2. Sum the counts in the 4.68-MeV energy peak for throrium-230, in the 4.79-MeV energy peak for neptunium-237, the 5.16 MeV energy peak for plutonium-239, and in all the peaks from 4.0 to 5.0 MeV for total uranium.
3. If poor separation is evidenced by the spectrum, rerun the analysis using freshly prepared columns.

### CALCULATION

$$A = (60) BCD/EF$$

where:

A = nuclide activity in the air filter, dpm;

B = total alpha counts for the nuclide;

C = alpha spectrometer efficiency factor, dpm/cpm;

D = sample-solution volume, ml;

E = counting time, sec; and

F = sample-solution aliquot, ml.

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Number 1635  
Analysis Th, U, Np, Pu  
Sample Air Filter  
Method Radiochemical  
Page 6 of 6

TECHNICAL PROCEDURES

TITLE: Sequential Determination of U, Th, Np, and Pu on Air Filters

Approvals:

A. H. Frazier  
Section Supervisor

R. W. Menden  
Department Head

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# ENVIRONMENTAL ANALYSIS PROCEDURE



UNION CARBIDE CORPORATION  
NUCLEAR DIVISION  
OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

NUMBER	EC-184
DATE	July 26, 1979
SUPERSEDES	
PAGE	1 OF 7

## STRONTIUM-90 IN WATER, RADIOCHEMICAL METHOD

### 1.0 SCOPE AND APPLICATION

- 1.1 This method is applicable to the determination of  $^{90}\text{Sr}$  in potable, natural, and industrial waters.
- 1.2 At ORNL, the lowest concentration reported is 0.004 pCi/ml when analyzing a 1-liter sample, counting for 30 minutes on a beta counter with a 0.6-cpm background and a 25% efficiency, and realizing an 80% chemical recovery of the strontium carrier.
- 1.3 At other UCC-ND plants, the lowest reported concentration is 0.02 pCi/ml for a 1-liter sample aliquot.

### 2.0 SUMMARY OF METHOD

- 2.1 Strontium carrier is equilibrated with the sample, precipitated as the insoluble carbonate, and separated from calcium and magnesium by nitrate precipitations followed by acetone washes. Further purification is accomplished by removing impurities with hydroxide scavenging and by removing barium as the chromate; final purification is made by precipitation of strontium as the oxalate which is mounted for beta counting and counted on a low-background beta counter.

### 3.0 SAMPLE HANDLING AND PRESERVATION

- 3.1 Samples are adjusted to a pH of 1.0 with nitric acid as soon as practicable, unless suspended and/or soluble strontium determinations are separately needed, in which case the samples are filtered before being adjusted with acid.
- 3.2 After preliminary treatment, the samples are stored in either glass or plastic containers.

### 4.0 INTERFERENCES

- 4.1 Strontium-89, when present in the sample, interferes with the beta counting of strontium-90. The presence of  $^{89}\text{Sr}$  can be ascertained by absorption studies; the interference of  $^{89}\text{Sr}$  can be circumvented by indirect determination of  $^{90}\text{Sr}$  via the  $^{90}\text{Y}$  daughter, after adequate ingrowth.
- 4.2 Strontium-90 is self-absorbing; therefore, the counting efficiency varies with the amount of solids on the mounts which are counted.

APPROVED BY Y-12 <i>R. M. McElaney</i>	APPROVED BY ORGDP <i>T. Kurovosh</i>	APPROVED BY UCC-ND COORD'R <i>C. W. White</i>
APPROVED BY PGDP <i>R. E. Simmons</i>	APPROVED BY ORNL <i>L. R. Lacey</i>	NUMBER EC-184

NUMBER	EC-184
DATE	July 26, 1979
SUPERSEDES	
PAGE	2 OF 7

## 5.0 APPARATUS

5.1 Lab glassware.

5.1.1 Beakers, size adequate for sample aliquot.

5.1.2 Centrifuge tubes, 50-ml glass.

5.2 Centrifuge.

5.3 Hot plate.

5.4 Ice bath.

5.5 Filter paper, #541 Whatman (11-cm).

5.6 Filter paper, #1 Whatman (18-mm).

5.7 Analytical balance.

5.8 Filter flask and funnel.

5.9 Fritted-glass filter crucibles.

5.10 Desiccator.

5.11 Low-background beta counter.

## 6.0 REAGENTS

6.1 Acetic acid, 6 M: Add 340 ml of glacial acetic acid ( $\text{CH}_3\text{COOH}$ ) to 500 ml of water and dilute to 1 liter with water.

6.2 Ammonium acetate solution, 6 M: Dissolve 462 grams of ammonium acetate ( $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$ ) in 500 ml of water and dilute to 1 liter with water.

6.3 Sodium carbonate solution, 2 M: Dissolve 248 grams of sodium carbonate monohydrate ( $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ ) in 700 ml of water and dilute to 1 liter with water.

6.4 Ammonium oxalate solution, saturated: Add 200 grams of ammonium oxalate monohydrate [ $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ ] to 500 ml of water in a 1-liter container, dilute to 1 liter with water, mix thoroughly, and let stand overnight before using.

- 6.5 Sodium chromate solution, 1.5 M: Dissolve 176 grams of sodium chromate quadrihydrate ( $\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$ ) in water and dilute to 500 ml with water.
- 6.6 Barium carrier solution, 10 mg Ba/ml: Dissolve 19.0 grams of barium nitrate [ $\text{Ba}(\text{NO}_3)_2$ ] in water and dilute to 1 liter with water.
- 6.7 Nitric acid, fuming.
- 6.8 Ferric nitrate solution, 50%: Dissolve 100 grams of ferric nitrate nonahydrate [ $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ] in water and dilute to 100 ml with water.
- 6.9 Ferric nitrate solution, 0.1 M: Dissolve 40.4 grams of ferric nitrate nonahydrate [ $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ] in water and dilute to 1 liter with water.
- 6.10 Nitric acid, 6 M: Add 375 ml of conc.  $\text{HNO}_3$  to 500 ml of water and dilute to 1 liter with water.
- 6.11 Acetone.
- 6.12 Sodium hydroxide solution, 19 M: Add 760 grams of sodium hydroxide ( $\text{NaOH}$ ) slowly with stirring to 500 ml of water and dilute to 1 liter with water. Store in a plastic container.
- 6.13 Ethyl alcohol, 95%  $\text{C}_2\text{H}_5\text{OH}$ .
- 6.14 Diethyl ether, anhydrous  $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$ .
- 6.15 Ammonium hydroxide, concentrated.
- 6.16 Strontium carrier solution: Dissolve 27.3 grams of strontium nitrate [ $\text{Sr}(\text{NO}_3)_2$ ] in a minimum of nitric acid and dilute to 1 liter with water.
  - 6.16.1 Standardization of strontium carrier: Pipet 5.00 ml of strontium carrier solution into a 100-ml beaker and add 30 ml of water. Adjust the pH to 9.0 with conc.  $\text{NH}_4\text{OH}$ , add 10 ml of saturated  $(\text{NH}_4)_2\text{C}_2\text{O}_4$  solution, and heat to nearly boiling with stirring. Cool to room temperature and quantitatively transfer the precipitate to a previously tared filter crucible with hot water. Wash the precipitate several times with hot water, three times with 10-ml portions of ethyl alcohol, and two times with 10-ml portion of diethyl ether. Desiccate the crucible and precipitate under vacuum to a constant weight. The net weight of the precipitate is the weight of strontium oxalate monohydrate ( $\text{SrC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ ) in 5.00 ml of the strontium carrier solution.

NUMBER	EC-184
DATE	July 26, 1979
SUPERSEDES	
PAGE	4 OF 7

- 6.17 Phenolphthalein indicator solution, 5% (w/v): Dissolve 5 grams of phenolphthalein ( $C_{20}H_{14}O_4$ ) in 50 ml of 95% ethyl alcohol and dilute to 100 ml with water.

7.0 PROCEDURE

- 7.1 Transfer a measured volume of the sample to an adequately sized beaker and adjust to a pH of 1.0 with nitric acid.
- 7.2 Add 1.00 ml of the standardized strontium carrier solution and 1 ml of 50% ferric nitrate solution.
- 7.3 Place on a hot plate and heat with stirring to near boiling. Digest for 20 minutes.
- 7.4 Cautiously add 19 M NaOH with stirring to a pH of 10.
- 7.5 Add 50 ml of 2 M  $Na_2CO_3$  solution and continue to digest on the hot plate with stirring for 30 minutes.
- 7.6 Remove from the hot plate and allow the precipitate to settle overnight.
- 7.7 Decant the supernatant liquid and discard it.
- 7.8 Transfer the precipitate to a 50-ml glass centrifuge tube, centrifuge for 5 minutes at 1500 rpm, and discard the supernatant liquid.
- 7.9 Wash the precipitate with 30 ml of water, centrifuge, and discard the water wash solution.
- 7.10 Dissolve the precipitate in a minimum of conc.  $HNO_3$ , then add 25 ml of fuming nitric acid.
- 7.11 Place the tube in an ice bath and stir the solution until precipitation is complete.
- 7.12 Remove the tube from the ice bath and centrifuge at 1500 rpm for 5 minutes. Decant the supernatant solution into a large volume of water and discard. Drain the tube completely, leaving no trace of  $HNO_3$ , as a precaution against any adverse reaction with the acetone wash which follows.
- 7.13 Add 30 ml of acetone and wash the precipitate thoroughly with stirring.

NUMBER	EC-184
DATE	July 26, 1979
SUPERSEDES	
PAGE	5 of 7

- 7.14 Centrifuge for 5 minutes at 1500 rpm and decant the acetone wash solution into a clearly-marked, organic-waste container.
- 7.15 Dissolve the precipitate in a minimum of water.
- 7.16 Repeat steps 7.10 through 7.14 starting with the addition of fuming  $\text{HNO}_3$  in step 7.10.
- 7.17 Dissolve the precipitate in 10 ml of water.
- 7.18 Add two drops of phenolphthalein indicator solution and 0.5 ml of 0.1 M  $\text{Fe}(\text{NO}_3)_3$  solution.
- 7.19 Add conc.  $\text{NH}_4\text{OH}$  dropwise with stirring until the phenolphthalein end point is reached, then add five more dro
- 7.20 Centrifuge for 5 minutes at 1500 rpm.
- 7.21 Filter the supernatant solution through #541 filter paper into another 50-ml glass centrifuge tube; discard the precipitate. Record the time at which the filtering is done as the separation time of  $^{90}\text{Sr}$  from  $^{90}\text{Y}$ . Wash the filter with 3 ml of water.
- 7.22 Neutralize the solution with 6 M  $\text{HNO}_3$ ; then add 1 ml of 6 M acetic acid, 2 ml of 6 M ammonium acetate, and 1 ml of barium carrier.
- 7.23 Heat the solution to near boiling; then add 1.5 M  $\text{Na}_2\text{CrO}_4$  solution dropwise with stirring to precipitate barium chromate. Chill in an ice bath and stir to complete the precipitation. Check for complete precipitation of Ba by adding a few more drops of  $\text{Na}_2\text{CrO}_4$ .
- 7.24 Centrifuge for 5 minutes at 1500 rpm.
- 7.25 Filter the supernatant solution through #541 filter paper into another 50-ml glass centrifuge tube and wash the filter with 3 ml of water. Discard the precipitate.
- 7.26 Add 2 ml of conc.  $\text{NH}_4\text{OH}$  to the solution and heat to boiling
- 7.27 Add 5 ml of saturated ammonium oxalate solution with stirring to precipitate the strontium oxalate.
- 7.28 Chill in an ice bath and continue to stir to complete the precipitation.



NUMBER	EC-184
DATE	July 26, 1979
SUPERSEDES	
PAGE	6 OF 7

- 7.29 Centrifuge for 5 minutes at 1500 rpm and discard the supernatant solution.
- 7.30 Place a tared 18-mm filter paper in the filtering funnel and wet with water, using vacuum on the filtering flask.
- 7.31 Transfer the precipitate onto the filter with hot water; then wash with two 10-ml portions of hot water, three 5-ml portions of 95% ethyl alcohol, and two 5-ml portions of diethyl ether.
- 7.32 Weigh the filter paper and precipitate, determine the chemical recovery, and mount for beta counting.
- 7.33 Count the sample mount without delay on a low-background beta counter.

#### 8.0 CALCULATIONS

$$^{90}\text{Sr}, \text{ pCi/ml} = A \cdot B \cdot C / D \cdot V$$

where:

A = net counts per minute of purified  $^{90}\text{Sr}$ ,

B = efficiency factor for  $^{90}\text{Sr}$ , including self-absorption correction,

C = conversion factor from dpm to pCi = 1 pCi/2.22 dpm,

D = fraction of strontium carrier recovered, and

V = volume of sample, ml.

#### 9.0 PRECISION AND ACCURACY

- 9.1 The precision at the 95% confidence level is  $\pm 12\%$ . The method exhibits a negative bias of 5% when applied to controls of known  $^{90}\text{Sr}$  concentration.

#### 10.0 REFERENCES

- 10.1 Hahn, R. B. and Straub, C. P., *Determination of Radioactive Strontium and Barium in Water*, J. Am. Water Works Assoc., 47, No. 4, 335 (1955).

NUMBER	EC-184
DATE	July 26, 1979
SUPERSEDES	
PAGE	7 OF 7

- 10.2 Kooi, J., *Quantitative Determination of Strontium-89 and Strontium-90 in Water*, Anal. Chem., 30, p. 532 (1958).
- 10.3 Franson, M. A., Editor, *Standard Methods for Examination of Water and Waste Water*, 14th Edition (1975).

# ENVIRONMENTAL ANALYSIS PROCEDURE



UNION CARBIDE CORPORATION  
NUCLEAR DIVISION  
OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

NUMBER
EC-134
DATE
December 8, 1980
SUPERSEDES
PAGE
1 OF 4

## GAMMA-RAY EMITTING NUCLIDES IN WATER, NONDESTRUCTIVE SPECTROMETRIC METHOD

### 1.0 SCOPE AND APPLICATION

- 1.1 This method is applicable to the identification and measurement of gamma-emitting nuclides in potable, industrial, and natural waters.
- 1.2 The minimum detection limits for radionuclides vary depending on gamma-ray branching ratios, counting geometry, photon-detection efficiency, and counting time. For  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ , the lowest concentration reported (LCR) can be as low as 2.5 pCi/L for a 900-ml sample contained in a Marinelli beaker and counted 16 hours on a Ge(Li) detector with a 20% efficiency.

### 2.0 SUMMARY OF THE METHOD

- 2.1 The sample (of known volume), contained in a polyethylene Marinelli beaker or wide-mouthed jar, is counted for a period of time sufficient to yield the desired sensitivity on a high-efficiency Ge(Li) detector and pulse-height analysis system.
- 2.2 The spectral data are recorded on magnetic tape, or other output device, and processed by any of several accepted gamma-ray, data-reduction methods (such as the MONSTR Program) to identify and quantify the radionuclides present in the sample.

### 3.0 SAMPLE HANDLING AND PRESERVATION

- 3.1 If samples are to be filtered to separate the particulate matter, the filtration should be performed as soon as practicable after sampling. After the sample has been filtered, the filtrate is adjusted to pH 1 (pH paper) with HCl.
- 3.2 If total activities are to be determined and no filtration is necessary, the sample is adjusted to pH 1 (pH paper) with HCl.
- 3.3 The sample is either transferred to counting containers or stored in glass or plastic containers.

APPROVED BY Y-12 <i>R. J. McElaney</i>	APPROVED BY ORGDP <i>T. Kurosaki</i>	APPROVED BY UCC-ND COORD'R <i>C. W. Weber</i>
APPROVED BY PGDP <i>R. E. Simmons</i>	APPROVED BY ORNL <i>W. R. Laing</i>	NUMBER EC-134

NUMBER EC-134
DATE December 8, 1980
SUPERSEDES
PAGE 2 OF 4

#### 4.0 INTERFERENCES

- 4.1 The high resolution afforded by the Ge(Li) spectrometer system minimizes interference among the radionuclides normally encountered.
- 4.2 When overlapping photopeaks exist, accepted computer routines can be applied to supply the information required for resolution; or, in rare cases, chemical separations may be required.

#### 5.0 APPARATUS

- 5.1 Polyethylene Marinelli beakers: 1-liter capacity.
- 5.2 Polypropylene jars: 8-cm diam by 8-cm depth.
- 5.3 Ge(Li) detector(s): 20% relative efficiency recommended.
- 5.4 Multichannel pulse-height analyzer: 4096 channels or better.
- 5.5 Magnetic tape storage device, or equivalent.
- 5.6 Micropipet: calibrated.

#### 6.0 REAGENTS

- 6.1 Mixed-radionuclide solution, standardized solution of mixed, gamma-ray-emitting radionuclides. Suitable standards are available on a non-periodic basis from NBS and several commercial suppliers.
- 6.2 Hydrochloric acid, conc HCl.

#### 7.0 STANDARDIZATION

- 7.1 Using a micropipet, transfer an aliquot of standardized, mixed-radionuclide solution to a Marinelli beaker or a jar. The activity of the aliquot should be suitable to the analytical range of interest.
- 7.2 Add distilled water and HCl to bring to the required volume and maintain a 1-N-acid concentration. Cap the container, seal with plastic tape, and mix well.
- 7.3 Place the container in a plastic bag to protect against contamination. Position on the Ge(Li) detector and accumulate a spectrum such that the photopeaks of the standard emissions have a net count approaching 10,000.

- 7.4 Transfer the spectrum to magnetic tape. Process these data to determine the net count rate,  $R_i$ , of each of the standard photopeaks.
- 7.5 Correct the information on the standard certificate for radioactive decay; and, with reference to the aliquot used, determine the photon emission rate,  $\gamma_i$ , for each nuclide at the time of measurement.
- 7.6 Compute the counting efficiency,  $\epsilon_i$ , at each energy:

$$\epsilon_i = R_i / \gamma_i$$

- 7.7 Using these data, make a plot of counting efficiency,  $\epsilon$ , as a function of gamma energy,  $E$ , on logarithmic paper. Draw a continuous curve through the plotted points to provide a graph useful for determining counting efficiency at any energy within the range of the calibration.

## 8.0 PROCEDURE

- 8.1 Place the sample container, Marinelli beaker or jar, in its plastic bag on the Ge(Li) detector and accumulate a spectrum over a period sufficient to provide desired sensitivity.
- 8.2 Transfer the spectrum to magnetic tape. Process these data to determine the energy and net count rate,  $R_i$ , of each photopeak in the spectrum.
- 8.3 With reference to gamma-ray energy graphs, Section 7.7, identify the radionuclides present in the sample.

## 9.0 CALCULATIONS

- 9.1 Compute the activity concentration of each radionuclide:

$$\text{pCi/L} = \frac{R_i \times C}{\epsilon_i(I_i)(L)}$$

where:  $R_i$  = net count rate in photopeak  $i$ , cps,

$\epsilon_i$  = counting efficiency at  $E_i$  (from 7.7), cps/dps,

$I_i$  = absolute intensity (abundance fraction) of emission at  $E_i$ ,

NUMBER EC-134
DATE December 8, 1980
SUPERSEDES
PAGE 4 OF 4

L = volume of sample, liters, and

C = conversion factor: 27 pCi/dps.

## 10.0 PRECISION AND ACCURACY

- 10.1 Precision is a function of activity and counting time and can be as low as 1%.
- 10.2 Accuracy is limited to  $\pm 6\%$  due to uncertainty in detector calibration.

## 11.0 REFERENCES

- 11.1 A Handbook of Radioactivity Measurements Procedures; NCRP Report No. 58, Nov. 1978.
- 11.2 Radiochemical Analytical Procedures for Analysis of Environmental Samples; EMSL-LV-0539-17, March 1979.
- 11.3 Radioactive Decay Gamma Ray Spectra Compilation; DLC-19; Union Carbide Corporation, Nuclear Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- 11.4 Emery, J. F. and Dyer, F. F.; MONSTR: Multi-Element Determination in Environmental Neutron Activation Analysis Using MONSTR; Proceedings of 2nd International Nuclear Methods in Environmental Research Conference; University of Missouri, Columbia, MO, July 29-31, 1974.

# ENVIRONMENTAL ANALYSIS PROCEDURE



UNION CARBIDE CORPORATION  
NUCLEAR DIVISION  
OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

NUMBER	EC-355
DATE	Nov. 26, 1979
SUPERSEDES	
PAGE	1 OF 4

## TECHNETIUM-99 IN SEDIMENT AND SOIL, RADIOCHEMICAL METHOD

### 1.0 SCOPE AND APPLICATION

- 1.1 This method is applicable to the measurement of technetium-99 in soil and in sediment from streams, lakes, and holding-ponds.
- 1.2 The lowest concentration reported is 20 pCi/g for a 0.2-g aliquot of a 40-g sample.

### 2.0 SUMMARY OF METHOD

- 2.1 Technetium-99 is leached from the sample with hot nitric acid, and the solution is filtered.
- 2.2 Persulfate is added to ensure oxidation of Tc to +7, and iron is added as a coprecipitant of impurities; e.g., uranium and its daughters.
- 2.3 The solution is made basic and centrifuged. A portion of the supernate is mixed with a liquid scintillator and the  $^{99}\text{Tc}$  is counted on a liquid-scintillation beta spectrometer.
- 2.4 A known amount of  $^{99}\text{Tc}$  is added, the mixture is counted again to determine counting efficiency, and the activity of  $^{99}\text{Tc}$  is calculated.

### 3.0 SAMPLE HANDLING AND PRESERVATION

- 3.1 Samples may be collected and stored in plastic or glass containers.
- 3.2 Samples are not dried, but are analyzed as-received. (If samples are heated in a drying oven, there is a possibility that Tc may be volatilized.)

### 4.0 INTERFERENCES

- 4.1 Interferences include beta-emitting nuclides that are soluble in a basic solution, such as  $^{90}\text{Sr}$ . Interference by high-energy beta emitters, such as  $^{40}\text{K}$ , is minimized by appropriate energy-window selection on the spectrometer.

APPROVED BY Y-12 <i>R. F. McEllaney</i>	APPROVED BY ORGDP <i>T. Kwanaguchi</i>	APPROVED BY UCC-ND COORD'R <i>C. W. Weber</i>
APPROVED BY PGDP <i>R. E. Simmons</i>	APPROVED BY ORNL <i>W. R. Loring</i>	NUMBER EC-355

NUMBER	EC-355
DATE	Nov. 26, 1979
SUPERSEDES	
PAGE	2 OF 4

## 5.0 APPARATUS

- 5.1 Liquid-scintillation beta spectrometer.
- 5.2 Liquid-scintillation counting vials, plastic or glass, 20-ml volume.
- 5.3 Centrifuge for 50-ml tubes.
- 5.4 Centrifuge tubes, plastic, 50-ml, scribed at the 40-ml level.
- 5.5 Filter paper, Whatman #41, size not critical.
- 5.6 Pipets, 50-microliter.

## 6.0 REAGENTS

- 6.1 Liquid-scintillation mix: Insta Gel, Packard Instrument Co.
- 6.2 Potassium persulfate solution, 5% w/v: Dissolve 50 g of  $K_2S_2O_8$  in water and dilute to 1 liter.
- 6.3 8 M  $HNO_3$ : Dilute 500 ml of conc  $HNO_3$  to 1 liter.
- 6.4 Ferric nitrate solution, 10% w/v: Dissolve 100 g of  $Fe(NO_3)_3 \cdot 9H_2O$  in water and dilute to 1 liter.
- 6.5 Technetium-99 standard solution, 200,000 dpm/ml, prepared by appropriate dilution of standard solution from Amersham/Searle.
- 6.6 Sodium hydroxide solution, saturated: Dissolve 347 grams in 100 ml of  $H_2O$ .

## 7.0 PROCEDURE

- 7.1 Weigh 40 grams of sample, as received, in a plastic petri dish and transfer to a 400-ml glass beaker.
- 7.2 Add, in increments of 5-ml, 200 ml of 8 M  $HNO_3$ . If frothing occurs with the addition of acid, add approximately 100 ml of  $H_2O$  before the addition of more acid.



Nov. 26, 1979

- 7.3 Heat at 60-80°C for 2 hours. (Do not boil or allow to go to dryness.)
- 7.4 Allow solids to settle, and decant the solution into a 1-liter glass beaker.
- 7.5 Repeat steps 7.2, 7.3, and 7.4 two times.
- 7.6 Evaporate the leach solution to 50 ml. (Do not boil or allow to go to dryness since Tc may be volatilized.)
- 7.7 Dilute the solution to approximately 150 ml, filter it into a 200-ml volumetric flask, and dilute to volume with 4 M HNO<sub>3</sub>.
- 7.8 Pipet 20 ml of the prepared solution into a 50-ml plastic centrifuge tube scribed for 40 ml.
- 7.9 Add 1 ml of K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> solution and 1 ml of ferric nitrate solution, and heat in a water bath at 60°C for 10 minutes. [K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> oxidizes Tc to +7; if the Tc is not oxidized, it will be coprecipitated subsequently with Fe(OH)<sub>3</sub>].
- 7.10 Add saturated NaOH solution until the sample solution is basic to pH paper.
- 7.11 Dilute the solution to 40 ml with water, and mix thoroughly with a glass stirring rod.
- 7.12 Centrifuge for 2 minutes.
- 7.13 Pipet 2 ml of the supernate into a liquid-scintillation counting vial, add 15 ml of liquid-scintillation mix, and mix thoroughly.
- 7.14 Count the <sup>99</sup>Tc for 20 minutes in a liquid-scintillation beta spectrometer.
- 7.15 Pipet 50 microliters of <sup>99</sup>Tc standard solution into the vial, shake, and count for 1 minute.
- 7.16 Count 15 ml of liquid-scintillation mix, and calculate the background in counts per minute.

## 8.0 CALCULATIONS

$$8.1 \quad ^{99}\text{Tc, pCi/g of sample} = \frac{A}{B-C} \cdot \frac{C \cdot D}{E \cdot F}$$

NUMBER	EC-355	
DATE	Nov. 26, 1979	
SUPERSEDES		
PAGE	4	OF 4

where:

A = activity of  $^{99}\text{Tc}$  standard addition, dpm,

B = count rate of  $^{99}\text{Tc}$  standard addition plus sample aliquot, corrected for background, cpm.

C = count rate of sample aliquot corrected for background, cpm,

D = dilution factor; e.g.,  $(40/2)(200/20) = 200$ ,

E = conversion factor = 2.22 dpm/pCi, and

F = weight of sample, g.

## 9.0 PRECISION AND ACCURACY

9.1 Analyses of known samples have indicated a limit of error, at the 95% confidence level, of  $\pm 200$  pCi/g at the 1250-pCi/g level. This approximates 8% relative standard deviation.

9.2 A positive bias of 100 pCi/g (8% relative) has been determined at the 1250-pCi/g level.

## 10.0 REFERENCE

10.1 Anders, Edward; The Radiochemistry of Technetium; NAS-NS-3021, National Academy of Sciences, November, 1960.

# ENVIRONMENTAL ANALYSIS PROCEDURE



UNION CARBIDE CORPORATION  
NUCLEAR DIVISION  
OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

NUMBER	EC-186
DATE	July 26, 1979
SUPERSEDES	
PAGE	1 OF 3

## TECHNETIUM-99 IN WATER, RADIOCHEMICAL METHOD

### 1.0 SCOPE AND APPLICATION

- 1.1 This method is applicable to the measurement of technetium-99 (Tc-99) in effluent and environmental water.
- 1.2 The lowest concentration reported is 0.3 pCi/ml, based on a one-liter sample.

### 2.0 SUMMARY OF METHOD

- 2.1 The sample is acidified with nitric acid, and potassium persulfate is added to ensure oxidation of technetium to Tc(VII). Iron(III) is added as a coprecipitant for uranium, thorium, and protactinium, and the solution is made basic. The solution is centrifuged and the Tc-99 in the supernate is counted on a beta liquid-scintillation spectrometer.

### 3.0 SAMPLE HANDLING AND PRESERVATION

- 3.1 Samples may be collected in glass or plastic containers.
- 3.2 Samples may be preserved by acidifying with 2 ml of 16 M nitric acid per liter.

### 4.0 INTERFERENCES

- 4.1 This method is designed for samples which may contain uranium and its daughters. Radionuclides such as K-40, Sr-90, and Cs-137, which are not coprecipitated with ferric hydroxide, interfere. Interference by beta emitters with maximum energies greater than that of Tc-99 (0.3 MeV), e.g., K-40 and Cs-137, is minimized by energy-channel selection on the spectrometer.

### 5.0 APPARATUS

- 5.1 Three-channel beta liquid-scintillation spectrometer and liquid-scintillation bottles.
- 5.2 Centrifuge and 50-ml plastic centrifuge tubes.

APPROVED BY Y-12 <i>R. E. Simmons</i>	APPROVED BY ORGDP <i>J. K. ...</i>	APPROVED BY UCC-ND COORD'R <i>C. W. ...</i>
APPROVED BY PGDP <i>R. E. Simmons</i>	APPROVED BY ORNL <i>L. R. ...</i>	NUMBER EC-186

NUMBER	EC-186
DATE	July 26, 1979
SUPERSEDES	
PAGE	2 of 3

## 6.0 REAGENTS

- 6.1 Liquid-scintillation mix: *Insta Gel*, Packard Instrument Co.
- 6.2 Standard Tc-99 solution: 300,000 disintegrations/min/ml (d/m/ml).
- 6.3 Sodium hydroxide solution, 40% W/V: Dissolve 40 g of NaOH in 100 ml of H<sub>2</sub>O.
- 6.4 Potassium persulfate solution, 5% W/V: Dissolve 5 g of K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> in 100 ml of H<sub>2</sub>O.
- 6.5 Ferric nitrate solution, 10% W/V: Dissolve 10 g of Fe(NO<sub>3</sub>)<sub>3</sub> in 100 ml of H<sub>2</sub>O.

## 7.0 PROCEDURE

- 7.1 Transfer 1 liter of sample to a 1500-ml beaker.
- 7.2 Add 2 ml of 16 M nitric acid (HNO<sub>3</sub>) and evaporate to 50-70 ml.
- 7.3 Transfer the solution to a 100-ml volumetric flask and dilute to volume with water.
- 7.4 Pipet 20 ml from the volumetric flask into a 50-ml plastic centrifuge tube that has previously been calibrated for 40 ml.
- 7.5 Add 1 ml of 16 M HNO<sub>3</sub> and 2 ml of potassium persulfate solution, and warm in a hot water bath at approximately 70°C for 10 min. [Note: K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> oxidizes Tc to Tc(VII), which remains in solution after the Fe(OH)<sub>3</sub> precipitation (7.6); Tc(IV) will coprecipitate with Fe(OH)<sub>3</sub>].
- 7.6 Cool the sample to room temperature, add 1 ml of ferric nitrate solution, and make basic with NaOH; ferric hydroxide precipitates. Check basicity with pH paper to ensure a pH >7.
- 7.7 Dilute to 40 ml with water, stir well, and centrifuge for 2 min.
- 7.8 Pipet 2 ml of the supernate into a liquid-scintillation bottle.
- 7.9 Add 15 ml of the liquid-scintillation mix and shake.
- 7.10 Place the sample in the beta liquid-scintillation spectrometer, and allow to cool for 20 min.
- 7.11 Count the sample for 20 min. using an energy channel of 0.05-0.3 Mev.

7.12 Add 50  $\mu$ l of standard Tc-99 solution and count for 1 min.

7.13 Run a reagent blank for background.

## 8.0 CALCULATION

$$A = BC/22.2(D-C)$$

where:

A = Tc-99 in sample, pCi/ml;

B = Tc-99 in standard addition, d/m;

C = counts/minute (c/m) of sample aliquot, corrected for background;

D = c/m of sample aliquot plus standard addition, corrected for background;

$$22.2 = 2.22 (d/m/pCi) \times \frac{1000 (\text{total ml sample})}{100 (\text{aliq. factor})}$$

## 9.0 PRECISION AND ACCURACY

9.1 The limit of error at the 95% confidence level is  $\pm 30$  pCi/ml at 300 pCi/ml. There is no significant bias.

## 10.0 REFERENCE

10.1 Anders, Edward, *The Radiochemistry of Technetium*, National Academy of Sciences, November 1960 (NAS-NS-3021).

# ENVIRONMENTAL ANALYSIS PROCEDURE



UNION CARBIDE CORPORATION  
NUCLEAR DIVISION  
OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

NUMBER	EC-350
DATE	July 26, 1979
SUPERSEDES	
PAGE	1 OF 7

## STRONTIUM-90 IN SEDIMENT AND SOIL, RADIOCHEMICAL METHOD

### 1.0 SCOPE AND APPLICATION

- 1.1 This method is applicable to the determination of strontium-90 in soil and sediment samples.
- 1.2 At ORNL, the lowest concentration reported is 0.2 pCi/g when analyzing a 10-g sample, counting for 30 minutes on a beta counter with a 0.6-cpm background and a 25% counting efficiency, and realizing an 80% chemical recovery for the strontium carrier.
- 1.3 At other UCC-ND plants, the lowest reported concentration is 1 pCi/g for 10-gram samples.

### 2.0 SUMMARY OF METHOD

- 2.1 A known weight of strontium carrier is added to the sample which is leached by hot nitric acid and hot nitric acid-hydrogen peroxide treatment. The leachate is reduced in volume, and the strontium is separated from calcium, magnesium, and rare earths by nitrate precipitation followed by acetone washes. Further purification is accomplished by removing yttrium and other impurities with hydroxide scavenging and by removing barium and radium as the chromates; final purification is made by precipitation of strontium as the oxalate, which is mounted for beta counting and counted on a low-background beta counter.

### 3.0 SAMPLE HANDLING AND PRESERVATION

- 3.1 The samples are oven-dried to a constant weight at 105°C, pulverized, screened to 100-mesh particle size, and thoroughly blended.
- 3.2 The prepared sample material is stored in airtight glass or plastic containers.

### 4.0 INTERFERENCES

- 4.1 Samples which are of a refractory nature, such as test-site materials, are not apt to release strontium in the leaching process; therefore, more rigorous treatment is recommended for decomposition of these samples.
- 4.2 Strontium-89, when present in the sample, interferes with the beta counting of strontium-90. The presence of  $^{89}\text{Sr}$  can be ascertained by absorption studies; the interference of  $^{89}\text{Sr}$  can be circumvented by indirect determination of  $^{90}\text{Sr}$  via the  $^{90}\text{Y}$  daughter, after adequate ingrowth.

APPROVED BY Y-12 <i>R. McElhenny</i>	APPROVED BY ORGDP <i>J. Kurovoshin</i>	APPROVED BY UCC-ND COORD'R <i>C. W. W. E. E. E.</i>
APPROVED BY PGDP <i>R. E. Simmons</i>	APPROVED BY ORNL <i>L. R. L. L.</i>	NUMBER EC-350

NUMBER	EC-350
DATE	July 26, 1979
SUPERSEDES	
PAGE	2 OF 7

- 4.3 Strontium-90 is self-absorbing; therefore, the counting efficiency varies with the amount of solids on the mounts which are counted.

## 5.0 APPARATUS

- 5.1 Drying oven, 105°C.
- 5.2 Muffle furnace, 500°C.
- 5.3 Hot plate with magnetic stirrer.
- 5.4 Centrifuge.
- 5.5 Screens, 40- and 100-mesh.
- 5.6 Analytical balance.
- 5.7 Pulverizer.
- 5.8 Magnetic stirring bar, teflon-coated, 1.5 inches long.
- 5.9 Lab glassware.
  - 5.9.1 Beakers, 250-ml size and 500-ml tall-form.
  - 5.9.2 Centrifuge tubes, 50-ml glass and 100-ml plastic.
  - 5.9.3 Fritted-glass filter crucibles.
- 5.10 Filter flask and funnel.
- 5.11 Filter paper, #541 Whatman (11 cm).
- 5.12 Filter paper, #1 Whatman (18 mm).
- 5.13 Ice bath.
- 5.14 Desiccator.
- 5.15 Low-background beta counter.

## 6.0 REAGENTS

- 6.1 Nitric acid, fuming.
- 6.2 Nitric acid, concentrated.

NUMBER	EC-350
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- 6.3 Nitric acid, 8 M: Add 500 ml of conc.  $\text{HNO}_3$  to 500 ml of water.
- 6.4 Nitric acid, 6 M: Add 375 ml of conc.  $\text{HNO}_3$  to 500 ml of water and dilute to 1 liter with water.
- 6.5 Ammonium hydroxide, concentrated.
- 6.6 Acetic acid, 6 M: Add 340 ml of glacial acetic acid ( $\text{CH}_3\text{COOH}$ ) to 500 ml of water and dilute to 1 liter with water.
- 6.7 Ammonium acetate solution, 6 M: Dissolve 462 grams of ammonium acetate ( $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$ ) in 500 ml of water and dilute to 1 liter with water.
- 6.8 Ammonium oxalate solution, saturated: Add 200 grams of ammonium oxalate monohydrate  $[(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}]$  to 500 ml of water in a 1-liter container, dilute to 1 liter with water, mix thoroughly, and let stand overnight before using.
- 6.9 Sodium chromate solution, 1.5 M: Dissolve 176 grams of sodium chromate quadrihydrate ( $\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$ ) in water and dilute to 500 ml with water.
- 6.10 Barium carrier solution, 10 mg Ba/ml: Dissolve 19.0 grams of barium nitrate  $[\text{Ba}(\text{NO}_3)_2]$  in water and dilute to 1 liter with water.
- 6.11 Acetone.
- 6.12 Hydrogen peroxide, 30% solution.
- 6.13 Phenolphthalein indicator solution, 5% (w/v): Dissolve 5 grams of phenolphthalein ( $\text{C}_{20}\text{H}_{14}\text{O}_4$ ) in 50 ml of 95% ethyl alcohol and dilute to 100 ml with water.
- 6.14 Ethyl alcohol, 95%  $\text{C}_2\text{H}_5\text{OH}$ .
- 6.15 Diethyl ether, anhydrous  $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$ .
- 6.16 Strontium carrier solution: Dissolve 27.3 grams of strontium nitrate  $[\text{Sr}(\text{NO}_3)_2]$  in a minimum of nitric acid and dilute to 1 liter with water.



6.16.1 Standardization of strontium carrier: Pipet 5.00 ml of strontium carrier solution into a 100-ml beaker and add 30 ml of water. Adjust the pH to 9.0 with conc.  $\text{NH}_4\text{OH}$ , add 10 ml of saturated  $(\text{NH}_4)_2\text{C}_2\text{O}_4$  solution, and heat to nearly boiling with stirring. Cool to room temperature and quantitatively transfer the precipitate to a previously tared filter crucible with hot water. Wash the precipitate several times with hot water, three times with 10-ml portions of ethyl alcohol, and two times with 10-ml portions of diethyl ether. Desiccate the crucible and precipitate under vacuum to a constant weight. The net weight of the precipitate is the weight of strontium oxalate monohydrate ( $\text{SrC}_2\text{O}_4 \cdot \text{H}_2\text{O}$ ) in 5.00 ml of the strontium carrier solution.

6.17 Ferric nitrate solution, 0.1M: Dissolve 40.4 grams of ferric nitrate nonahydrate [ $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ] in water and dilute to 1 liter with water.

## 7.0 PROCEDURE

- 7.1 Transfer a measured weight (5-10 g) of 100-mesh sample to a 500-ml tall-form beaker. If the sample is thought to contain organic matter, ash in a muffle furnace at 500°C for several hours before continuing.
- 7.2 Slowly add 50-75 ml of 8M  $\text{HNO}_3$  allowing sufficient time for any foaming to subside.
- 7.3 Add 1 ml strontium carrier solution.
- 7.4 Carefully introduce the magnetic stirring bar, place on the hot plate, and digest with stirring at 90°-95°C for one hour.
- 7.5 Remove from the hot plate and transfer the sample solution to a 100-ml plastic centrifuge tube.
- 7.6 Centrifuge for 10 minutes at 1500 rpm.
- 7.7 Decant the supernatant liquid into a 250-ml beaker and retain.
- 7.8 Rinse the residue from the centrifuge tube into the original 500-ml beaker with 50-75 ml of 8M  $\text{HNO}_3$ .
- 7.9 Return to the hot plate and digest with stirring at 90°-95°C for one hour with the addition of a few drops of 30% hydrogen peroxide intermittently for a total of 5-10 ml.

- 7.10 Repeat steps 7.5 through 7.7.
- 7.11 Repeat step 7.8 using 25 ml of 1 M  $\text{HNO}_3$ .
- 7.12 Repeat steps 7.9 and 7.10 and discard the residue.
- 7.13 Place the 250-ml beaker containing the leach solution on a hot plate and reduce the volume to 15 ml.
- 7.14 Transfer the sample solution to a 50-ml glass centrifuge tube, rinsing the 250-ml beaker with a minimum of fuming  $\text{HNO}_3$ .
- 7.15 Add fuming  $\text{HNO}_3$  to give a total volume of 40 ml.
- 7.16 Place the 50-ml tube in an ice bath and digest the sample with frequent stirring for 30 minutes to precipitate the nitrates.
- 7.17 Remove the tube from the ice bath and centrifuge for 10 minutes at 1500 rpm. Decant the supernatant solution into a large volume of water and discard.
- 7.18 Dissolve the precipitate in a minimum of water.
- 7.19 Add 15 ml of fuming  $\text{HNO}_3$  and 15 ml of conc.  $\text{HNO}_3$ .
- 7.20 Repeat steps 7.16 and 7.17.
- 7.21 Drain the tube completely, leaving no trace of  $\text{HNO}_3$ , as a precaution against any adverse reaction with the acetone wash which follows.
- 7.22 Add 30 ml of acetone and wash the precipitate thoroughly with stirring.
- 7.23 Centrifuge for 5 minutes at 1500 rpm and decant the acetone wash into a clearly-marked, organic-waste container.
- 7.24 Repeat steps 7.18, 7.19, 7.16, and 7.17.
- 7.25 Repeat steps 7.21, 7.22, and 7.23.
- 7.26 Dissolve the precipitate in 10 ml of water.
- 7.27 Add two drops of phenolphthalein indicator solution and 0.5 ml of 0.1 M  $\text{Fe}(\text{NO}_3)_3$  solution.

NUMBER	EC-350
DATE	July 26, 1979
SUPERSEDES	
PAGE	6 OF 7

- 7.28 Add conc.  $\text{NH}_4\text{OH}$  dropwise with stirring until the phenolphthalein end-point is reached, then add five more drops.
- 7.29 Centrifuge for 5 minutes at 1500 rpm.
- 7.30 Filter the supernatant solution through #541 filter paper into another 50-ml glass centrifuge tube; discard the precipitate. Record the time at which the filtering is done as the separation time of  $^{90}\text{Sr}$  from  $^{90}\text{Y}$ . Wash the filter with 3 ml of water.
- 7.31 Neutralize the solution with 6 M  $\text{HNO}_3$ ; then add 1 ml of 6 M acetic acid, 2 ml of 6 M ammonium acetate, and 1 ml of barium carrier.
- 7.32 Heat the solution to near boiling; then add 1.5 M  $\text{Na}_2\text{CrO}_4$  solution dropwise with stirring to precipitate barium chromate. Chill in an ice bath and stir to complete the precipitation. Check for complete precipitation of Ba by adding a few more drops of  $\text{Na}_2\text{CrO}_4$ .
- 7.33 Centrifuge for 5 minutes at 1500 rpm.
- 7.34 Filter the supernatant solution through #541 filter paper into another 50-ml glass centrifuge tube and wash the filter with 3 ml of water. Discard the precipitate.
- 7.35 Add 2 ml of conc.  $\text{NH}_4\text{OH}$  to the solution and heat to boiling.
- 7.36 Add 5 ml of saturated ammonium oxalate solution with stirring to precipitate the strontium oxalate.
- 7.37 Chill in an ice bath and continue to stir to complete the precipitation.
- 7.38 Centrifuge for 5 minutes at 1500 rpm and discard the supernatant solution.
- 7.39 Place a tared 18-mm filter paper in the filtering funnel and wet with water, using vacuum on the filtering flask.
- 7.40 Transfer the precipitate onto the filter with hot water; then wash with two 10-ml portions of hot water; three 5-ml portions of 95% ethyl alcohol; and two 5-ml portions of diethyl ether.
- 7.41 Weigh the filter paper and precipitate, determine the chemical recovery, and mount for beta counting.
- 7.42 Count the sample mount without delay on a low-background beta counter.

## 8.0 CALCULATIONS

$$^{90}\text{Sr}, \text{ pCi/g} = A \cdot B \cdot C / D \cdot V$$

where:

A = net counts per minute of purified  $^{90}\text{Sr}$ ,

B = efficiency factor for  $^{90}\text{Sr}$ , including self-absorption correction,

C = conversion factor from dpm to pCi = 1 pCi/2.22 dpm,

D = fraction of strontium carrier recovered, and

V = weight of sample, grams.

## 9.0 PRECISION AND ACCURACY

9.1 The precision at the 95% confidence level is  $\pm 12\%$ .

9.2 The method exhibits a positive bias of 25% when applied to controls of known  $^{90}\text{Sr}$  concentration.

## 10.0 REFERENCES

- 10.1 Hahn, R. B. and Straub, C. P., *Determination of Radioactive Strontium and Barium in Water*, J. Am. Water Works Assoc., 47, No. 4, 335, (1955).
- 10.2 Kooi, J., *Quantitative Determination of Strontium-89 and Strontium-90 in Water*, Anal. Chem., 30, p. 532, (1958).
- 10.3 Franson, M. A., Editor, *Standard Methods for Examination of Water and Waste Water*, 14th Edition, (1975).